CHAPTER 6

RESULTS AND DISCUSSION

It is a customary practice to represent the results obtained in a systematic or scientific way. In this context the results pertaining to VAaRS based on the analysis performed in the former three chapters (i.e. theory, simulation/ model and experiments) are discussed here in Chapter 6. Theoretical analysis of vapour adsorption refrigeration system had been described in Chapter 3. It is observed from the analysis that operating parameters such as desorption temperature, condenser temperature and evaporator temperature besides mass concentration ratio at the end of desorption and at the end of adsorption influence greatly the performance of the system. The analysis involved the environment friendly pair of working fluids namely, activated carbon – methanol and zeolite – water. The theoretical results are shown in figures 6.1 to 6.27. In Chapter 4, a novel analytical tool named ‘SAARS’ has been described in detail. This technique helps to identify the optimal performance at different operating conditions and is presented in figures 6.28 to 6.41. The experimental studies as described in Chapter 5 were conducted on an intermittent adsorption refrigeration system capacity of 0.25 kW working with activated carbon – R152a and AC-methanol as working pairs. The results are presented in figures. 6.42 to 6.46.
6.1 RESULTS OF THEORETICAL ANALYSIS

The operating parameters such as generator, evaporator and condenser temperatures are chosen such that they satisfy the requirements as discussed in the Chapter 3. The theoretical analysis are also involved, a parametric study of the adsorption system that has been carried out with the help of simulation code written in MATLAB. The simulated results are compared with the published data available in literature. Figure 6.1 shows the COP variation with respect to $T_{\text{gen}}$ wherein, Pons and Grenier (1987) results are used to compare for given pair (zeolite- water). It is noted from the figure that the COP computed is in good agreement with the experimental results available in literature within the range of +4% to -6%.

![Figure 6.1 Plot of COP vs $T_{\text{gen}}$ for $T_{\text{cond}}$=308 K](image-url)
6.2 RESULT OF ZEOLITE - WATER ADSORPTION SYSTEM

6.2.1 Effect of condenser temperature

The condenser temperature is one of the most influencing parameter that affects the performance of the system. Figure 6.2 shows the effect of condenser temperature on COP. It is observed that COP decreases when condenser temperature increases. This decrease in COP attributed to reduction on refrigerating effect at the given heat input.

Figure 6.3 illustrates the effect of condenser temperature on Carnot COP of the system. Carnot COP of the system increases with increase in condenser temperature. It is understood that increase in condenser temperature rises generation temperature of the system and hence Carnot COP increases with increase in condenser temperature. In contrast that Carnot COP also decrease with increase in evaporator temperature is also observed.

![Figure 6.2 Plot of COP vs T_{cond} for M_{max} = 0.2, M_{min} = 0.1, Q_{evap} = 1000 kJ/hr](image-url)
Figure 6.3 Plot of $\text{COP}_{\text{Carnot}}$ vs $T_{\text{cond}}$ for $M_{\text{max}} = 0.2$, $M_{\text{min}} = 0.1$, $Q_{\text{evap}} = 1000$ kJ/hr

Figure 6.4 Plot of $\text{SCP}$ vs $T_{\text{cond}}$ for $M_{\text{max}} = 0.2$, $M_{\text{min}} = 0.1$, $Q_{\text{evap}} = 1000$ kJ/hr
Figure 6.4 indicates the effect of condenser temperature on SCP. It can be seen that SCP decreases linearly with increase in condenser temperature. This variation is observed because higher condenser temperature reduces the refrigerating effect and hence SCP reduces. It is also noted that at higher evaporator temperatures the SCP of the system increases. This trend is opposite to Carnot COP results, and is evident from figures 6.3 and 6.4.

6.2.2 Effect of evaporator temperature

The evaporator temperature is also the most influencing parameter that affects the performance of the system. Even though this parameter is user desired value, analyses have been carried out to understand the effect of evaporator temperature on the performance of the System.

Figure 6.5 illustrates the variation of COP with evaporator temperature. It is noted that an increase in evaporator temperature at the given condenser temperature helps to rise the refrigeration effect. Hence at a given heat input, COP increases with increase in evaporator temperature. It is further understood that a higher condenser temperature reduces the refrigerating effect. This is the reason for drop in COP at higher condenser temperature.

Figure 6.6 shows the effect of evaporator temperature on Carnot COP of the system. It is observed that increase in evaporator temperature will attribute to decrease in Carnot COP of the System. When evaporator temperature increased the temperature difference to be maintained is reduced, and Carnot COP of the system decreases.
Figure 6.5 Plot of COP vs $T_{\text{evap}}$ for $M_{\text{max}} = 0.2$, $M_{\text{min}} = 0.1$, $Q_{\text{evap}} = 1000$ kJ/hr

Figure 6.6 Plot of $\text{COP}_{\text{Carnot}}$ vs $T_{\text{evap}}$ for $M_{\text{max}} = 0.2$, $M_{\text{min}} = 0.1$, $Q_{\text{evap}} = 1000$ kJ/hr
Figure 6.7 Plot of SCP vs $T_{\text{evap}}$ for $M_{\text{max}} = 0.2$, $M_{\text{min}} = 0.1$, $Q_{\text{evap}} = 1000$ kJ/hr

Figure 6.7 depicts the effect of evaporator temperature on SCP of the system. It is observed that increase in evaporator temperature will attribute to increase in SCP of the System. When evaporator temperature increased temperature difference to be maintained is reduced, and hence the refrigerating capacity increases and desired cooling effect is achieved quickly than in earlier case. All these factors lead to increase in SCP of the system with increase the evaporator temperature.

6.2.3. Effect of generation temperature

The generation temperature is said to be maximum temperature observed at the end of the desorption process cycle. Adsorption refrigeration process being a heat operated system, it is necessary to analyse the effect of generation temperature on performance characteristics of the system. The effect of generation temperature on the COP, SCP of the system is higher than other parameters. Figure 6.8 shows the effect
of generation temperature on COP at different condenser temperature. As desorption temperature increases, mass of vapour desorbed increase causing refrigerating capacity to increase. Hence COP of the system is increasing. However after certain desorption temperature the drop in concentration ratio plays a major role and affects the COP. Increases in mass concentration influence the heat of generation to increase causing COP to decrease. Figure 6.9 shows the effect of generation temperature on the COP of the system. It is observed that the COP of system increases up to certain generation temperature and starts falling down afterwards. This variation of COP with generation temperature is attributed to reasons cited for figure 6.8. From figures 6.8 and 6.9, it is obvious that either increase in evaporator or decrease in condenser temperature yield to higher refrigeration effect or COP or vice-versa.

Figure 6.8 Plot of COP vs $T_{\text{gen}}$ for $M_{\text{max}} = 0.25$, $T_{\text{evap}}$=274K, $Q_{\text{evap}} = 1000$ kJ/hr
Figure 6.9 Plot of COP vs $T_{\text{gen}}$ for $M_{\text{max}} = 0.25$, $T_{\text{cond}}=298\,\text{K}$, $Q_{\text{evap}} = 1000\,\text{kJ/hr}$

Figure 6.10 presents the effect of generation temperature on the Carnot COP of the system. Carnot COP of the system increases with increase in generation temperature. A rise in generation temperature leads to increase in refrigeration capacity of the system. This causes the Carnot COP to increase with increase in generation temperature of the system.

Figure 6.11 shows the effect of generation temperature on Carnot COP of the system at different evaporator temperature. As stated above, increase in generation will lead to increase in Carnot COP of the system. It is also observed that evaporator temperature had no or negligible effect on Carnot COP at constant generation temperature.
Figure 6.10 Plot of $\text{COP}_{\text{Carnot}}$ vs $T_{\text{gen}}$ for $M_{\text{max}} = 0.25$, $T_{\text{evap}} = 274\, \text{K}$, $Q_{\text{evap}} = 1000\, \text{kJ/hr}$

Figure 6.11 Plot of $\text{COP}_{\text{Carnot}}$ vs $T_{\text{gen}}$ for $M_{\text{max}} = 0.25$, $T_{\text{cond}} = 298\, \text{K}$, $Q_{\text{evap}} = 1000\, \text{kJ/hr}$
Figure 6.12 illustrates the effect of generation temperature on SCP of the system. An increase in generation temperature improve desorption process cause SCP or refrigerant capacity to increase. However, after a particular value of desorption temperature increases, the rate of desorption process reduces due to pressure built-up in the adsorption bed. It is also understood that at higher condenser temperature the SCP gets lowered.

The Figure 6.13 portrays the effect of generation temperature on SCP of the system at different evaporator temperatures. The SCP found to be increased with increase in generation temperature as in Figure 6.12. It is clearly understood for the evaporator temperature range(s) has little effect on SCP of the system at constant generation temperatures.

Figure 6.12 Plot of SCP vs \( T_{\text{gen}} \) for \( M_{\text{max}} = 0.25, T_{\text{evap}}=274K, Q_{\text{evap}} = 1000 \text{ kJ/hr} \)
Figure 6.13 Plot of SCP vs $T_{gen}$ for $M_{max} = 0.25$, $T_{cond} = 298K$, $Q_{evap} = 1000$ kJ/hr

6.2.4 Effect of generation temperature on COPs

Figure 6.14 represents the effect of generation temperature on theoretical COP, solar COP and Carnot COP for constant cooling load ($Q_{evap} = 1000$ kJ/hr), it is observed that the value of Carnot COP is more, when compared with theoretical and solar COP, since the Carnot COP is estimated by considering the medium as ideal.
6.3 RESULT ANALYSIS ON AC – METHANOL ADSORPTION SYSTEM

6.3.1. Effect of condenser temperature

Figure 6.15 shows the effect of condenser temperature on COP. It is observed that COP decreases as the condenser temperature decreases. This decrease in COP attributed to reduction on refrigerating effect at the given heat input. To maintain the evaporating capacity it is necessary to have additional mass of adsorbent in the system. Also it appears that the trend of the curve shows a non-linear behaviour of condenser temperature on COP of the system. From Figure 6.16 it is understood that Carnot COP remains constant or decrease little with increase in condenser temperature. In contrast to the above, it is observed that a steep increase of Carnot COP in case of zeolite-water pair as seen in figure 6.3. This is attributed by lower
generation or desorption temperatures in case of AC-methanol and while it is higher with zeolite-water pair adsorption refrigerant system.

Figure 6.17 shows the effect of condenser temperature on SCP. It can be seen that Specific Cooling Power (SCP) decreases linearly with increase in condenser temperature. This effect is observed because higher the condenser temperature reduces the refrigerating effect and SCP reduces. It is also noted that at higher evaporator temperatures, SCP of the system increases.

Figure 6.15 Plot of COP vs $T_{\text{cond}}$ for $M_{\text{max}} = 0.20$, $M_{\text{min}}=0.10$, $Q_{\text{evap}}=1000$ kJ/hr
Figure 6.16 Plot of COP\textsubscript{Carnot} \textit{vs} \textit{T}_{\text{cond}} for \textit{M}_{\text{max}} = 0.20, \textit{M}_{\text{min}}=0.10,\textit{Q}_{\text{evap}}=1000\text{ kJ/hr} 

Figure 6.17 Plot of SCP \textit{vs} \textit{T}_{\text{cond}} for \textit{M}_{\text{max}} = 0.20, \textit{M}_{\text{min}}=0.10,\textit{Q}_{\text{evap}}=1000\text{ kJ/hr}
6.3.2 Effect of evaporator temperature

Figure 6.18 illustrates the variation of COP with evaporator temperature. It is noted that an increase in evaporator temperature at the given condenser temperature helps to rise the refrigeration effect. Hence at a given heat input COP increases with increase in evaporator temperature. It is further understood that a higher condenser temperature reduces the refrigerating effect. This is the reason for drop in COP at higher condenser temperature.

Figure 6.19 shows the variation of Carnot COP with evaporator temperature. But similar to the condenser temperature, the evaporator temperature also has negligible effect on Carnot COP of the system. This behaviour is attributed to similar reasons stated for condenser temperature in figure 6.16.

![Figure 6.18 Plot of COP vs T_{evap} for M_{max} = 0.20, M_{min}=0.10, Q_{evap}=1000 kJ/hr](image-url)
Figure 6.19 Plot of $\text{COP}_{\text{Carnot}}$ vs $T_{\text{evap}}$ for $M_{\text{max}} = 0.20, M_{\text{min}} = 0.10, Q_{\text{evap}} = 1000$ kJ/hr

Figure 6.20 Plot of $\text{SCP}$ vs $T_{\text{evap}}$ for $M_{\text{max}} = 0.20, M_{\text{min}} = 0.10, Q_{\text{evap}} = 1000$ kJ/hr
Figure 6.20 depicts the effect of evaporator temperature on SCP of the system. It is observed that increase in evaporator temperature will attribute to increase in SCP of the System. When evaporator temperature increased, the temperature difference to be maintained is reduced and hence refrigerating capacity increases therefore the desired cooling effect is achieved quickly than in earlier case. All these factors lead to increase in SCP of the system with increase in evaporator temperature.

6.3.3 Effect of generation temperature

Figure 6.21 shows the effect of generation temperature on COP at different condenser temperature. When desorption temperature increases, mass of vapour desorbed increases therefore the refrigerating capacity increases and hence COP of the system is increasing. However after certain desorption temperature, the drop in concentration ratio plays a major role and affects the COP. When the change in mass concentration increases, heat of generation also will increase therefore COP tends to decrease. It is further observed that higher is the condenser temperature, results in lowering of the COP of the system. Figure 6.22 shows the influence of generation temperature on the COP of the system. It is observed that the COP of system increases up to certain generation temperature and starts falling down afterwards as shown in figure. This variation of COP with generation temperature is attributed to reasons cited for figure 6.5. It is noted that higher is the evaporator temperature then the COP also increases. Figure 6.23 presents the effect of generation temperature on the Carnot COP of the system. Carnot COP of the system increases with increase in generation temperature of the system. A rise in generation temperature leads to increase in refrigeration capacity of the system. This causes the Carnot COP to increase with increase in generation temperature of the system. It is also observed that condenser temperature has no significant effect on Carnot COP.
Figure 6.21 Plot of COP vs $T_{\text{gen}}$ for $M_{\text{max}} = 0.25$, $T_{\text{evap}} = 274$K, $Q_{\text{evap}} = 1000$ kJ/hr

Figure 6.22 Plot of COP vs $T_{\text{gen}}$ for $M_{\text{max}} = 0.25$, $T_{\text{cond}} = 298$K, $Q_{\text{evap}} = 1000$ kJ/hr
Figure 6.23 Plot of $\text{COP}_{\text{Carnot}}$ vs $T_{\text{gen}}$ for $M_{\text{max}} = 0.25$, $T_{\text{evap}}= 274K$, $Q_{\text{evap}}= 1000$ kJ/hr

Figure 6.24 Plot of $\text{COP}_{\text{Carnot}}$ vs $T_{\text{gen}}$ for $M_{\text{max}} = 0.25$, $T_{\text{cond}}= 298K$, $Q_{\text{evap}}= 1000$ kJ/hr
Figure 6.24 shows the effect of generation temperature on Carnot COP of the system at different evaporator temperatures. As stated above increase in generation temperature will lead to increase in Carnot COP of the system. It is also observed that evaporator temperature had no or negligible effect on Carnot COP at constant generation temperature.

Figure 6.25 illustrates the effect of generation temperature on SCP of the system. It is noted that SCP increases with an increase in generation temperature. When the desorption temperature increases, rate of desorption process increases, and the refrigerant capacity also increases and hence SCP of the system increases. However, after a particular value of desorption temperature increasing the rate of desorption process reduces which is due to pressure built-up in the adsorption bed. It is also understood that at higher condenser temperature SCP gets lowered.

Figure 6.25 Plot of SCP vs $T_{\text{gen}}$ for $M_{\text{max}} = 0.25$, $T_{\text{evap}}=274K$, $Q_{\text{evap}}=1000$ kJ/hr
Figure 6.26 portrays the effect of generation temperature on SCP of the system at different evaporator temperatures. The SCP found to be increase with increase in generation in a similar reason mentioned for the Figure 6.7. It is clearly understood from the figure that evaporator temperature has no significant effect on SCP of the system for same generation temperatures.

6.3.4. Effect of generation temperature on COPs,

Figure 6.27 shows the effect of generation temperature on Theoretical COP, Solar COP and Carnot COP for constant cooling load ($Q_{evap} = 1000$ kJ/hr). It is observed that the value of Carnot COP is more when compared with theoretical and solar COP, since Carnot COP is estimated by considering the medium as ideal.
6.4 SIMULATION ANALYSIS (SAARS)

SAARS Optimizer is an multi functional tool capable of design and analysis of complete solar powered adsorption refrigeration system. The main features of the SAARS is its capability to analysis the performance of the system and to predict the optimal value of parameters that to be maintained in operation and to obtain maximum performance of the system. This multi functional tool is also helpful in designing the evaporator, condenser, solar collector. The ability of comparing two or more adsorption pairs in several aspects is also incorporated in this tool. Dynamic analysis of adsorption refrigeration system can also done using this tool.

6.4.1. SAARS simulator results

SAARS simulator having extended capabilities is used to study the effects of minimum and maximum mass concentration ratios on COP and SCP of the system.

Figure 6.27 Plot of COPs vs $T_{\text{gen}}$ for $M_{\text{max}} = 0.25$, $T_{\text{cond}}=298K$, $T_{\text{evap}}=274K$
All the analysis had been carried out at constant evaporator temperature, condenser temperature, and refrigerating capacity of the evaporator. Since, it had already analysed the effect of above said parameters towards the performance of the system in Chapter 4. The results thus obtained are shown in figures 6.28 to 6.41.

Figure 6.28 shows, how maximum mass concentration ratio influences the COP of the system. The COP tends to increase first and then decreases when, $M_{\text{min}}$ increases at particular value of $M_{\text{max}}$. It can be understood from the process of adsorption and desorption that the heat of generation is the combined effect of rise in temperature associated with desorption and drop or rise in mass concentration ratio. It is observed from figure that the influence of drop in mass concentration ratio is more, when compared to rise in temperature during desorption. This causes rise in COP at lower range of minimum concentration. However, after the point of inversion, the influence of temperature rise dominates more than drop in mass concentration ratio.

![Figure 6.28 Influence of minimum mass concentration ratio on COP at](image-url)

Figure 6.28 Influence of minimum mass concentration ratio on COP at $T_{\text{evap}}=274$ K, $T_{\text{cond}}=298$ K, $Q_{\text{evap}}=1000$ kJ/hr for zeolite-water

99
rise in desorption temperature leads to increase in value of temperature difference between adsorption and desorption causing drop in COP and a decrease after the point of inversion.

Figure 6.29 indicates that the system COP increases with the value of maximum concentration increasing. It is understood that at particular refrigerating capacity of the system the rise in temperature of desorption dominates the difference in mass concentration ratio. Hence, the COP of the system increases with increase in $M_{\text{max}}$. However, It is learned that if higher is the value of $M_{\text{min}}$, the value of COP becomes more. All the characteristics lines of COP at different $M_{\text{min}}$ tend to converge to a point of saturation.

Figure. 6.29 Influence of maximum mass concentration ratio on COP at $T_{\text{evap}}=274$ K, $T_{\text{cond}}=298$ K, $Q_{\text{evap}} =1000$ kJ/hr for zeolite-water
Figure 6.30 illustrates the effect of both minimum and maximum mass concentration ratios on COP of zeolite–water adsorption refrigeration system. As discussed earlier the COP increases first and then decreases after particular point of maximum mass concentration ratio. The same trend is observed for effect of minimum mass concentration ratio on COP. This behavioural change is attributed to the influence of mass concentration ratio and rise in bed temperature.

Figure 6.31 illustrates the effect of both minimum and maximum mass concentration ratios on COP for AC-methanol adsorption refrigeration system as a three dimensional view. Unlike refrigeration system with zeolite-water pair, the COP of VA_{dR} system with AC-methanol increases with increase in maximum concentration ratio. While the COP decreases with increase in minimum mass concentration ratio.

Figure 6.32 shows the effect of minimum mass concentration ratio on SCP at different maximum mass concentration ratios. It is identified that if minimum mass concentration ratio increases the SCP of the system decreases linearly. This is because increase in minimum mass concentration ratio will decrease the desorption mass and cooling capacity for a mass of the adsorbent decreases.

Figure 6.33 shows the effect of maximum mass concentration ratio on SCP at different minimum mass concentration ratios. Increasing the maximum mass concentration ratio will extend the working range of the adsorption pairs. Increasing the woking range will increase the cooling capacity obtained per kg of adsorbent used. This lead to decrease in SCP when maximum concentration ratio is increased.
Figure. 6.30 Influence of mass concentration ratios on COP for zeolite-water

Figure. 6.31 Influence of mass concentration ratios on COP for AC-methanol
Figure. 6.32 Influence of minimum mass concentration ratio on SCP at 
\[ T_{\text{evap}} = 274 \text{ K}, T_{\text{cond}} = 298 \text{ K}, \ Q_{\text{evap}} = 1000 \text{ kJ/hr} \] for Zeolite-water

Figure. 6.33 Influence of maximum mass concentration ratio on SCP at 
\[ T_{\text{evap}} = 274 \text{ K}, T_{\text{cond}} = 298 \text{ K} \] 
\[ Q_{\text{evap}} = 1000 \text{ kJ/hr} \] for Zeolite-water
Figures 6.34 and 6.35 show the influence of mass concentration ratios on SCP of system for zeolite – water and activated carbon – methanol pairs respectively. It can be seen that SCP increases, when increasing the working range of the adsorption pairs. To have a maximum specific cooling power from the system, it should be operated between the possible minimum and maximum concentration ratios.

6.4.2 **Comparison of adsorption pairs using SAARS Optimizer**

The present research presents the theoretical analysis of two adsorption pairs in brief namely, activated carbon – methanol and zeolite – water respectively. The figure 6.36 to 6.40 illustrates a relative performance analysis on above mentioned adsorption pairs. The effects of condenser temperature, evaporator temperature and generation temperature on COP and SCP of the system are discussed below. Figure 6.36 shows the effect of condenser temperature on COP for two different adsorption systems. It is observed from the figure that activated carbon – methanol adsorption system produces a higher COP value, this is because of the lower heat of adsorption and higher adsorption capacity for activated carbon – methanol adsorption system. It is further understood that at higher condenser temperature the COP of the system gets lowered for both adsorption system.

Figure 6.37 depicts the variation of COP of the system at various evaporator temperatures for two different adsorption systems. It can be understood that activated carbon – methanol adsorption system produced a higher COP value, this is because of the lower heat of adsorption, higher adsorption capacity and higher cooling density per kg of adsorbent for activated carbon – methanol pair. It is also portrays that at higher evaporator temperature, the COP of the system increases for both adsorption system.
Figure. 6.34 Influence of mass concentration ratios on SCP for Zeolite-water

Figure. 6.35 Influence of mass concentration ratios on SCP for AC-methanol
Figure 6.36 Effect of condenser temperature on COP for two different adsorption pairs for $T_{\text{evap}} = 274$ K, $M_{\text{max}} = 0.2$, $M_{\text{min}} = 0.1$, $Q_{\text{evap}} = 1000$ kJ/hr.

Figure 6.37 Effect of evaporator temperature on COP for different adsorption pairs. $T_{\text{cond}} = 298$ K, $M_{\text{max}} = 0.2$, $M_{\text{min}} = 0.1$, $Q_{\text{evap}} = 1000$ kJ/hr.
Figure 6.38 represents the effect condenser temperature on SCP of the system for two different adsorption systems. Zeolite – water system provided higher SCP than Activated carbon – methanol adsorption system. It is learned that higher SCP of zeolite – water system is because of higher heat of vaporisation and higher adsorption heat. It is also understood that at higher condenser temperature, the COP of the system decreases for both adsorption system.

Figure 6.39 shows the effect evaporator temperature on SCP of the system for two different adsorption systems. It can be observed that both adsorption pairs have no effect on SCP at different evaporator temperatures. However, zeolite – water adsorption system has higher SCP values than activated carbon – methanol system, because of the similar reason stated for figure 6.38.

Figure 6.40 shows the effect of generation temperature on COP of the system for two different adsorption systems. It is observed that activated carbon – methanol can produce higher COP value. This increased COP attribute to higher cooling capacity, low operating temperature and lower boiling point of methanol.

Figure 6.41 shows the effect generation temperature on SCP of the system for two different adsorption systems. It is observed that at higher generation temperatures, the zeolite – water adsorption system was working in an efficient way. It is learned that higher SCP values is because of higher heat of adsorption for zeolite and water pair. So, it can be concluded that for a possible low generating temperature applications AC-methanol provide higher performance. On the other hand at higher generating temperatures the zeolite – water adsorption system can be used.
Figure 6.38 Effect of condenser temperature on SCP of different adsorption pairs.

\[ T_{\text{evap}} = 274 \, \text{K}, \, M_{\text{max}} = 0.2, \, M_{\text{min}} = 0.1, \, Q_{\text{evap}} = 1000 \, \text{kJ/hr} \]

Figure 6.39 Effect of evaporator temperature on SCP for different adsorption pairs.

\[ T_{\text{cond}} = 298 \, \text{K}, \, M_{\text{max}} = 0.2, \, M_{\text{min}} = 0.1, \, Q_{\text{evap}} = 1000 \, \text{kJ/hr} \]
Figure 6.40 Effect of generation temperature on COP for different adsorption pairs.

\[ T_{\text{evap}} = 274 \text{ K}, \ T_{\text{cond}} = 298 \text{ K}, \ M_{\text{max}} = 0.2, \ Q_{\text{evap}} = 1000 \text{ kJ/hr} \]

Figure 6.41 Effect of generation temperature on SCP for different adsorption pairs.

\[ T_{\text{evap}} = 274 \text{ K}, \ T_{\text{cond}} = 298 \text{ K}, \ M_{\text{max}} = 0.2, \ Q_{\text{evap}} = 1000 \text{ kJ/hr} \]
6.4.3 Prediction of optimal process parameters using SAARS Optimizer

SAARS Optimizer is capable of analyzing thousands of combinations of operating parameters and finding out parameters in which performance of system is maximum. For an adsorption system operating using zeolite - water adsorption pair for which the evaporator temperature at 275 K, condenser temperature at 298 K and refrigerating capacity of system to be 1000 kJ/hr, the following results were obtained from the optimiser to have maximum COP of the system.

- Minimum mass concentration ratio to be maintained = 0.09
- Maximum mass concentration ratio to be maintained = 0.20
- Pressure at evaporator side (0.007771574 Bar) = 0.777 kN/m²
- Pressure at condenser side (0.032503408 Bar) = 3.250 kN/m²
- Mass of adsorbent required = 4.21 kg
- Mass of refrigerant required = 0.84 kg
- Maximum cycle temperature = 442.7 K
- Required heat input = 2289.74 kJ/hr
- COP of system = 0.436
- Carnot COP of the system = 1.509
- Thermal Efficiency of the System = 28.93%
- Specific Cooling Power = 1188.93 kJ/kg
6.5 RESULTS OF EXPERIMENTAL INVESTIGATION OF AC-METHANOL

The results of the experiments with AC-methanol has been summarized in the Table 6.1 and the effect of generation temperature on performance parameters of the system is shown in figures 6.42 to 6.44.

Figure 6.42 compares the experimental results obtained with the similar experiments conducted by Anyanwu (2004). It is observed that at higher generation temperature increases the quantity of refrigerent desorbed from the bed and also increases the COP of the system. Both the results are found to follow a similar trend and has very less deviations.

Table 6.1 Summary of data using methanol

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Figure 6.42 Validation of experimental results

Figure 6.43 Plot of COP’s vs generation temperature
Figure 6.43 shows the effect of generation temperature on COP\textsubscript{I}, COP\textsubscript{II}, COP\textsubscript{Solar} and COP\textsubscript{Carnot}. It is observed that the value of COP\textsubscript{Carnot} is more when compared with other COP\textsubscript{I} and solar COP. Since COP\textsubscript{Carnot} is estimated by considering the medium as ideal. COP\textsubscript{I}, COP\textsubscript{II}, COP\textsubscript{Solar} is increasing steadily upon increasing generation temperature but COP\textsubscript{Carnot} increasing up to a generation temperature of certain value and has a decreasing trend afterwards.

Figure 6.44 shows the variation of SCP, Q\textsubscript{evap} and water bath temperature (evaporator) on generation temperature. As generation temperature increases the amount of refrigerating effect is observed and indirectly increases the Q\textsubscript{evap}. This is attributed to reasons cited for increase in COP with increase in generation temperature. It is observed that the change in generation temperature does affect the refrigeration effect at constant evaporation temperature. An increase in SCP is also observed for a generation temperature increase. The rise in SCP with increase in generation temperature is attributed to variation in refrigeration capacity with desorption temperature as discussed earlier. It is observed that the change in generation temperature has very high impact on variation of SCP. Further, generation temperature increase causing a decrease in evaporator temperature and is obvious from Figure 6.44. In contrast to former two parameters’ variation with generation temperature an opposite trend is observed with that of water bath temperature (evaporator) indicates more cooling load or refrigerating capacity/ effect. This trend had been observed earlier in the simulation studies too.
6.6 RESULTS OF EXPERIMENTAL INVESTIGATION OF AC-R152a

The results of the experiments with AC-R152a have been summarized in the Table 6.2 and the effect of generation temperature on performance parameters of the system is shown in figures 6.45 to 6.46.

It is observed from the results of AC-R152a and that of AC-methanol both the pairs represent the similar trends or behavior but with different range of numerical values of the parameters.
Table 6.2 Summary of data using R152a

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>$T_{\text{gen}}$ (°C)</td>
<td>65</td>
<td>70</td>
<td>74</td>
<td>78</td>
</tr>
<tr>
<td>$T_{\text{cond}}$ (°C)</td>
<td>32</td>
<td>31</td>
<td>33</td>
<td>34</td>
</tr>
<tr>
<td>$T_{\text{evap}}$ (°C)</td>
<td>-5</td>
<td>-7</td>
<td>-7</td>
<td>-10</td>
</tr>
<tr>
<td>$T_{\text{ads}}$ (°C)</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>$T_{\text{amb}}$ (°C)</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>$T_{\text{w,initial}}$ (°C)</td>
<td>24</td>
<td>23</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>$T_{\text{w,final}}$ (°C)</td>
<td>10</td>
<td>8</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>$Q_{\text{evap}}$ (kJ)</td>
<td>586</td>
<td>628</td>
<td>753</td>
<td>795</td>
</tr>
<tr>
<td>$Q_{\text{gen}}$ (kJ)</td>
<td>6543</td>
<td>6612</td>
<td>6668</td>
<td>6724</td>
</tr>
<tr>
<td>$Q_{\text{gi}}$ (kJ)</td>
<td>8146</td>
<td>7995</td>
<td>8234</td>
<td>8350</td>
</tr>
<tr>
<td>COP I</td>
<td>0.090</td>
<td>0.095</td>
<td>0.113</td>
<td>0.118</td>
</tr>
<tr>
<td>COP_{\text{Solar}}</td>
<td>0.072</td>
<td>0.079</td>
<td>0.092</td>
<td>0.095</td>
</tr>
<tr>
<td>COP_{\text{carnot}}</td>
<td>1.869</td>
<td>1.890</td>
<td>1.964</td>
<td>1.735</td>
</tr>
<tr>
<td>COP II</td>
<td>0.048</td>
<td>0.050</td>
<td>0.058</td>
<td>0.068</td>
</tr>
<tr>
<td>SCP (kJ/kg)</td>
<td>73.255</td>
<td>78.488</td>
<td>94.185</td>
<td>99.418</td>
</tr>
</tbody>
</table>

Figure 6.45 Plot of COPs vs generation temperature
Figure 6.46 Variation of SCP, $Q_{\text{evap}}$ and $T_w$ with generation temperature.