Study on the performance of adsorption cooling systems for small scale application : Activated carbon powder (ACP) - alcohol pairs

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Name

論 文 名：　Study on the performance of adsorption cooling systems for small scale application: Activated carbon powder (ACP) - alcohol pairs　（小規模アプリケーション用活性炭−エタノール系 吸着冷却システムの性能に関する研究）

Title

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論 文 内 容 の 要 旨

Thesis Summary

This thesis presents the performance results of an adsorption cooling systems employing activated carbon powder, namely Maxsorb III as the adsorbent and two types of alcohols namely ethanol and methanol as the refrigerant. Extensive experiment and simulation have been conducted to show the effect of the operating conditions and heat exchanger design on the adsorption cooling system performances and the results are furnished in seven chapters.

A comprehensive literature review on the development of adsorption cooling systems employing activated carbon as the adsorbent and alcohol as the refrigerant are presented. The main challenge in adsorption system is to make a compact chiller which is suitable for a small scale application and at the same time produce at least minimum 2 kW cooling capacity with a *COP* of minimum 0.5. Unfortunately, based on the current study, present performance is far beyond the minimum target point. The main reasons of the low performance are due to the unnecessary energy losses which result from periodic heating and cooling, refrigerant loss and also the low heat transfer rate of the activated carbon during the adsorption/desorption phase. Therefore, a comprehensive adsorption system performance analysis is necessary based on the actual experimental conditions, i.e. heat transfer fluid temperature and cycle time.

From the above perspective, the performance of four beds of adsorber operating as one bed adsorber heat exchanger of plate-fin and micro-tube type are described. The heat exchangers used were specially designed to increase the amount of activated carbon packing density but at the same time to reduce the heat exchanger mass and volume compared to the commercially available fin tube heat exchanger. The performance of an adsorption cooling system has been experimentally investigated by varying the heat source temperatures ranging from 70 to 90 °C. The suitability of the ACP-ethanol working pair with the current heat exchangers namely adsorber/desorber, evaporator and condenser are

also evaluated. The results showed that the heat losses would cause severe degradations in the coefficient of performance (*COP*) in the actual system. Besides that, the experimental study has revealed that the evaporator used was not suitable with the low pressure refrigerant.

A few modifications were made to the experimental apparatus in order to enhance the system performances, and the total ACP mass were reduced as only two adsorber beds were used. The evaporator was replaced with the plate-fin tube evaporator with spray from 5 cm above the top of the evaporating tube. The performance of the heat exchanger calculated from the theoretical analysis was compared with the experimental data and it was found that the theoretical *COP* is about 60% higher than the experimental *Intrinsic COP,* which means that the new evaporator did not supplied enough ethanol refrigerant to the adsorber. It was noticed that the pre-cooling and pre-heating time should be optimized to ensure refrigerant gas adsorption and desorption, respectively at maximum capacity. Besides that, based on several other modifications, such as pipe arrangement, change in heat transfer medium, etc. on the experimental apparatus, the *Intrinsic COP* was improved from 0.05 to 0.18 at 80 °C heat source temperature.

Experimental investigations of an adsorption cooling system under equilibrium conditions have been performed to predict the cycle performance of one bed adsorber system. The total ACP mass were reduced as only one adsorber was used to ensure that the evaporator supply enough refrigerant to the adsorber. The experiment was conducted on five different pre-cooling and pre-heating settings and the heat balance were analyzed critically and the optimum cycle time were determined experimentally. The pre-cooling and pre-heating time for each adsorption and desorption process is discussed by identifying the suitable adsorbent pressure and temperature of the system. Considering the maximum cooling performance, the present experiments indicated an optimal pre-cooling/preheating time to be 60 second and the *Intrinsic COP* was increased up to 0.43 which is close to the theoretical *COP* value.

A lumped parameter model of an adsorption cooling system utilizing activated carbon powder (ACP) as adsorbent and alcohols (ethanol/methanol) as the refrigerant were presented. Firstly, the model was validated with the experimental study which consists of one bed adsorption cooling system employing ACP-ethanol pair. Then, the influence of the heat exchanger parameters on the performance of the system was studied. Compared with the current system, it was found that the system performance was improved with the smaller value of heat exchanger heat capacity and higher value of the number of transfer unit, *NTU.* Finally, the performance of the system with methanol as the alternative refrigerant was predicted, and it was found that ACP-methanol could be achieved approximately 40% improvement in *SCP* values and 3-7 % improvement in *COP* values as compared to those of ACP-ethanol working pair.

The present data are found to be useful in designing high performance, compact adsorption cooling system.