学　位　論　文　内　容　の　要　旨

博士の専攻分野の名称　　博士（工学）　　氏名　薛　成勲

学　位　論　文　題　名

Study on Adsorption Heat Pump Using Composite Natural Mesoporous Material as Low-Carbon Air Conditioning
(天然メソポーラス材料を用いた吸着式ヒートポンプによる低炭素空調)

Because of increasing concerns about energy saving and environmental issues resulted from air-conditioning, AHP has been considered as one of promising solution to relieve the problems. Furthermore, recently increasing interest on utilization of waste heat and reduced price of solar collectors are good opportunity for AHP systems to be more widespread. However, limitations such as expensive initial cost, relatively large system volume and low COP compared to other types of cooling system need to be improved. Therefore, as a part of effort to overcome these hinderances, this study presents several research topics in each chapter as followings.

In Chapter 1, comprehensive review of various AHP systems was provided. The advantages which make AHP system promising were clarified, and disadvantages to improve are also pointed out. Various AHP systems, several representative working pairs and commercialized AHP units were also introduced.

In Chapter 2, the natural mesoporous material based composite adsorbent impregnated with lithium chloride was introduced. The obvious enhancement of the equilibrium adsorption amount was obtained by impregnating LiCl into the pure WSS. The maximum applicable amount of the lithium chloride for preventing carryover was determined to be 20 wt.%, based on its pore volume. However, one major concern of applying the composite adsorbent is stability. To investigate physical stability after the impregnation, the experiments comparing the physical and equilibrium adsorption properties were conducted. WSS hardly showed change in physical properties after impregnation and the equilibrium adsorption amount also did not changed. Therefore, it was concluded that WSS is expected to be utilized as a host matrix of composite adsorbent in terms of both enhanced equilibrium adsorption amount and physically stable pore structures.

In Chapter 3, the mass transfer characteristics of water vapor on the coated adsorbent layer were studied. The coated type adsorbers have advantage of the better heat transfer from the metal of heat exchanger to the coated layer, and the adsorbent can be used more effectively. The mass transfer characteristic of the coated layer was dependent on thickness of the layer. Here, the mass transfer was divided into interfacial and internal to estimate effect of coated thickness, by using a novel experimental method. The experimentally obtained and calculated overall mass transfer coefficients based on the LDF model were matched acceptably, implying the applicability of the suggested experimental method.

In Chapter 4, the mass and heat transfer characteristics of the filled type adsorbers were studied. The mass transfer coefficient of each adsorber was calculated using the LDF model considering thermal

effects. During the experiments, the adsorbent temperature was controlled by adjusting the temperature of the cooling water from 30 to 60^oC. The overall heat transfer coefficient was experimentally evaluated by changing the adsorbent temperature from 80 to 30^oC to realize the actual working conditions of an AHP. The experimentally obtained heat and mass transfer coefficients were substituted into a mathematical model for a more accurate and practical estimation of the AHP performance. WSS composite material exhibited a COP that was 6 to 17 % higher than that of the A-type silica gel. This indicates the effectiveness of the WSS composite compared with the frequently used A-type silica gel.
In Chapter 5, the simulation analysis on the annual cooling performance of the solar assisted AHP which WSS composite as an adsorbent was conducted. The analysis was based on the mathematical model applying four difference climate conditions. WSS + LiCl 20 wt. % exhibited high adsorption capability, which allows the system to be operated with a longer cycle time to reduce the heat loss occurs when switching between adsorption and desorption modes. Indeed, the average temperature of the regeneration water for the half cycle time of 14 minutes was about 9.7^oC higher than the case of 8 minutes. Thus, WSS+LiCl 20 wt. % showed about 14 % of increase in AHP cooling performance as extending the half cycle time from 8 minute to 14 minute. The payback periods estimated based on the annual energy saving obtained from AHP and the local electricity cost were 6.6 years for Hawaii, 15.6 years for Dubai, respectively.

In Chapter 6, thermodynamic characteristics regarding energy and exergy are analyzed based on the experimental data using 1 kW-scale AHP system. The cooling capacity when the regeneration temperature is 70 ℃ was about 36 % reduced than that of the case with the regeneration water of 80^oC. Meanwhile, the decrease in the cooling capacity was much more severe when applying the regeneration water of 60^oC. The irreversibility tended to increase as the heat source temperature rises since the entropy generation increased as the heat source temperature increased. The inlet temperature of chilled water affected more than the temperature of regeneration water does; the lower irreversibility was observed at the lower chilled water temperature.

In Chapter 7, several future research topics were introduced. Based on the advantage of being easily combined with other types of cycles, it seems that various challenges regarding hybrids cycles of AHP systems will be possible. It is also expected that system characteristics will be quite different from the basic AHP systems for the case of the hybrid system with other types of cycles. Therefore, these hybrid cycles will be attractive topics as future researches.