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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　賀　方

学 位 論 文 題 名

Study on the Performance Enhancement of the Adsorption Heat Pump applied Natural Meso-porous Material

(天然メソポーラス材料を用いた吸着式ヒートポンプの性能向上に関する研究)

Global energy consumption has increased with technological advances, the air conditioner market is expected to burgeon. As a side effect of the use of traditional compress-type air conditioners, problems such as CO2 emissions and ozone layer depletion need to be addressed. Adsorption heat chiller or adsorption heat pump (AHP) is a type of thermally driven heat pump that provides cooling capacity using low-grade heat sources from 60 - 80 ° C, e.g., factory exhaust or hot water from a solar water heater. The utilization of water as adsorbate leads it to be environment friendly. Therefore, AHP is considered an attractive solution. However, some disadvantages such as the low Coefficient of cooling Performance (COP), exorbitant initial cost and huge entire size compared to other types of thermally driven heat pump such as Absorption Heat Pump, result in market barriers for AHPs.

A composite adsorbent of Wakkanai Siliceous Shale (WSS) impregnated with 20 wt.

In Chapter 1, the study background is introduced. The global energy consumption and the domestic energy consumption are introduced, which indicate the energy consumption increasing for the space cooling. Then the performance and specification of several thermal driven heat pumps are compared.

In Chapter 2, a comprehensive review of the AHP is conducted. The working pair, the advanced cycle for performance enhancement and the prior study in our laboratory are shown. Based on this review, the position and objective of this study are determined.

In Chapter 3, the WSS composite adsorbent is applied in a labo-scale AHP as the practical application study. The acrylics who inner diameter of 450 mm is used as the container to observe inside the AHP. The adsorbent is filled into the aluminum corrugated micro channel heat exchanger (HEX, W400 × H300 × D12) to manufacture the adsorbent-filled HEX (ad-HEX). Foundation performance experiments were conducted, and the COP of 0.45 and Specific Cooling Power (SCP) of 0.41 kW/kg are obtained under the following experimental conditions: regeneration at 80 ℃, condensation, and sorption at 30 ℃, chilled water of 15 ℃, and cycle time of 14 min. Further, Heat Recovery (HR) is introduced and experimentally studied to reduce the regeneration heat amount, and the heat balance for this AHP was evaluated. It is confirmed that two types of heat recoveries could improve the COP for this AHP up to 0.54 when the outlet temperature of both adsorbers is 55 ° C. The COP could be further improved to 0.57, based on the calculation for the heat balance. This AHP has advantages of high SCP as compared with AHPs in other formal studies.

In Chapter 4, author focuses on the improvement of the ad-HEX. A filling method known as the dip-coating method is introduced to improve the heat transfer and packing density of the ad-HEX. However, the dip-coating method results in the leakage of the impregnated LiCl, which effects on the adsorption ability of the adsorbent. Hence the dip-coating method is adapted to accommodate the WSS composite adsorbent, and two types of adsorbent-filled HEX (ad-HEX), i.e., the dip-HEX and dip-filled-HEX, are compared with the conventional ad-HEX known as the filled-HEX. The dip-HEX comprises a few mass transfer channels and has a packing density similar to that of the filled-HEX. Meanwhile, the dip-filled-HEX exhibits a 30

In Chapter 5, a three-dimensional model is formulated to predict and analyze the performance of an AHP with HR and Mass Recovery (MR). A new value factor index (VF) is proposed to determine the parameters for optimal system performance. It was confirmed that this model is suitable for performance prediction. COP can be improved from 0.503 to 0.604 at a cycle period of 14 min, which is consistent with the results of our previous study. An optimal HR period of 24 min is determined based on VF. Subsequently, MR was introduced. In cases where the MR of 1 s is utilized, SCP is increased from 0.389 kW/kg to 0.393 kW/kg, while the COP is increased to 0.607 with the HR. In addition, the COP decreased with an increase in the mass recovery period. It was found that the accumulated recoverable sensible heat is shared by the HR and MR. The HR reduces the accumulated regeneration heat. The MR not only reduced the regeneration heat but also enhanced the sorption process.

In Chapter 6, the conclusions for each chapter are summarized. The Passive Heat Recovery, which is one type of the heat recovery, is proved to improve COP from 0.45 up to 0.51. The adapted Dip-coating method also effective to enhance both COP and SCP. Based on the simulation result, both COP and SCP can be enhanced with the Mass Recovery. However, the performance improvement is negligible and the fulfilling is difficult. As the prospective topic, the case study using the simulation model built in Chapter 5 is needed. The specification design of the AHP can be evaluated according to the performance prediction results, which fit the climatic conditions of different area. In order to overcome the disadvantage that the unavailable cooling output below 0 ℃, the methanol is applied in some AHP as the adsorbate instead of the water. Moreover, it is possible to produce pure water by the adapted AHP system, which called water harvesting. With these study and development, AHP and other adsorption-based system are expected to be attractive.