Study on the PV Driven Dehumidifying System with Oyster Shell and Thermoelectric Device

Myoung-Jun Kim[*†] · Gyu-Hoon Chea[**]

*, ** Department of Power System Engineering, Kunsan Natioanl University, Kunsan, 573-701, Korea

굴패각과 열전소자를 이용한 태양광 구동형 제습시스템에 관한 연구

김명준[*†] · 채규훈[**]

*, ** 군산대학교 해양과학대학 동력기계시스템공학과

Abstract : *This paper has dealt with the probability of oyster shell desiccant cooling system driven by renewable energy of photo-voltaic effect. For this, fundamental experiments have been carried out focusing on the observation of dehumidifying effect of oyster shell and peltier elements used for air conditioning system. From this study, it is found that oyster shell has sufficient probability for using as a desiccant in air-conditioning system. Moreover, the heat releasing device(peltier element) can be used with direct current from PV cells so the system can be operated with high efficiency. As a result, the absolute humidity in a test chamber was reasonably controlled by oyster shell and peltier elements. Also the photo-voltaic energy from sun was enough for running power of this system.*

Key Words : *New and Renewable Energy, Photo Voltaic Energy, Oyster Shell, Peltier Element, Desiccant Cooling System*

요   약 : 본 연구는 수산 폐기물인 굴패각을 공조시스템의 수분 흡착제로 사용하기 위한 가능성을 실험을 통해 살펴본 기초적인 연구이다. 연구의 주된 목적은 굴패각의 제습성능과 열전소자의 냉각효과를 파악하는 것이며 본 연구를 통해 굴패각은 공조시스템 내에서 사용가능한 수분 흡착제로서의 성능을 충분히 가지고 있으며, 또한 냉각효과를 통해 흡착성능을 크게 향상시킬 수 있다는 것을 알았다. 본 시스템은 신재생에너지인 태양광을 이용하기 때문에 시스템의 구동에 필요한 다른 전원은 필요 없어 환경적으로도 매우 바람직한 연구이다.

핵심용어 : 신재생에너지, 태양광에너지, 굴패각, 페르체소자, 흡착식 냉각시스템

1. Introduction

Recent years, the crisis of energy is growing seriously and also the contamination of ecology have been reverberated as international problems(Lee, 2000). The social concern with energy crisis has been growing for the last several years. To realize effective air conditioning system and to solve the energy problem, the desiccant cooling system and its adoption idea are in the spotlight of new concept of air conditioning system. This study is to introduce the new concept of air conditioning system driven by photo voltaic energy as operating power and oyster shell used for desiccant from fishery wastes.

In warm climates, cooling is important for space conditioning of most buildings and the cooling load in refrigerator or air conditioning system increases during the daytime. So the efforts of reducing the cooling load have been performed at many places and it is regarded as necessary key point to who design the system of cooling.

The adsorption operations exploit the ability of certain solids preferentially to concentrate specific substances from solution onto their surfaces. In this manner, the components of either gaseous or liquid solutions can be separated from each other. In the field of gaseous separations, adsorption is used to dehumidifying air and other gases, to remove objectionable odors and impurities from industrial gases such as carbon dioxide, to recover valuable solvent vapors form dilute mixtures with air and other gases, and to fractionate mixtures of hydrocarbon gases containing such substances as methane, ethylene, ethane, propylene, and propane.

Some studies(Cooer and Alley, 1994; Benitez, 1993;

---

† Corresponding author : mjkim@kunsan.ac.kr, 063-469-1849

Buonicore and Davis, 1992; Nevers, 1995; Noll et al., 1992; Dubinin, 1995; Polanyi, 1932) on desiccant are concentrated in finding and developing the raw material of adsorbent.

The goal of this study is to clarify the possibility of oyster shell as a desiccant in a air conditioning system. Especially, the peltier element and photo voltaic cells were used for remove adsorption heat generation of oyster shell in the process of adsorption.

2. Experiment of Adsorption Amount of Adsorbent with Adsorption Mechanism

Fig. 1 show the apparent(Fig. 1(a), (b)) and microscopic photo(Fig. 1(c)) of oyster shell. Generally known, oyster shell has many cavities on its surface and these are widening the surface area. The table 1 shows the typical specific surface areas of adsorbents for usually used in industrial fields.

The specific surface area of activated carbon indicates the most high value than others in Table 1.

Although the value of oyster shell is very low. It can be derived from nature without any other efforts and costs.

(a) Real size　　(b) Particle state　　(c) Micro size

Fig. 1. Apparent and microscopic photos of oyster shell.

Table 1. Typical specific surface areas of adsorbents

Adsorbent	Asur [m^2/g]
Activated carbon	300~1,500
Activated alumina	200~400
Silica	300~900
Shell-based carbon	800~1,500
Oyster shell*(Particle) dave = 1.0[mm]	3.35~1.95
*mainly used in this study with consideration of probability on the usage of desiccant	

Under the constant temperature condition, the process of adsorption on porous material can be illustrated as Fig. 2. It is mainly divided into three steps as follows(Kondo, et al, 2003).
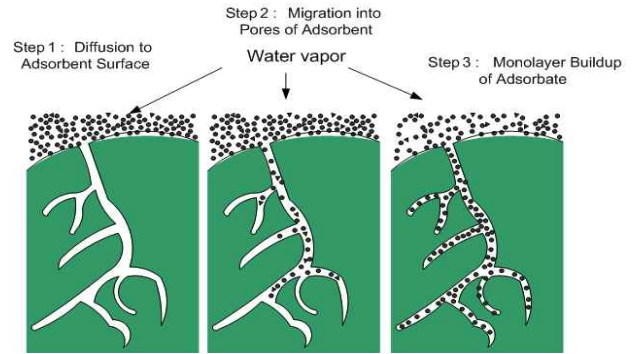

Fig. 2. Mechanism of adsorption.

▶ Step 1 : Molecule diffusion process into the thin layer of fluid(Called as fluid film) which is attached on the adsorbent.
▶ Step 2 : According to developing of diffusion, the surface diffusion process which attached the vapour or gas along the pores. It is called as mixed diffusion because there exist two diffusion of pore diffusion and surface diffusion.
▶ Step 3 : Adsorption process in the pore adsorption sites.

As mentioned at introduction, to investigate the probability of oyster shell as a desiccant, some desiccants were used for examining the adsorption amount of vapour on their surfaces. Fig. 3 is the schematic of experiment.
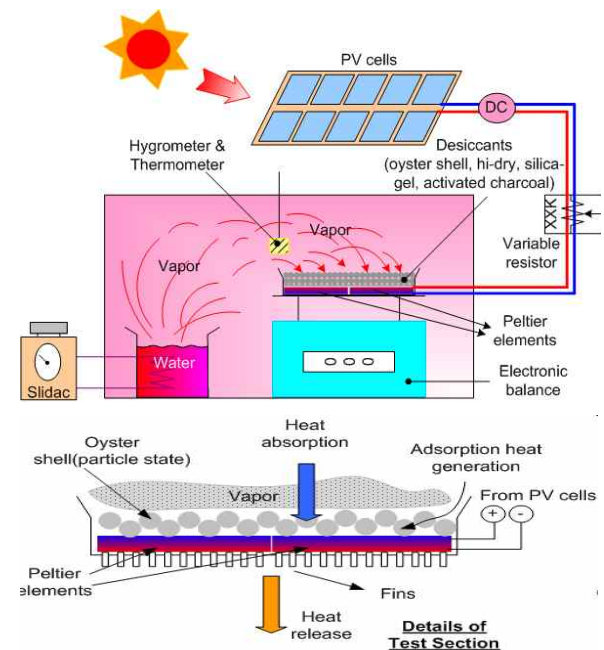

Fig. 3. Experimental schematic for measuring adsorption amount.

The apparatus is mainly consisted of constant temperature and humidity chamber(Samheung instrument, SH-FDO 150), electronic balance(OHAUS, adventurer, ±2 mg) and test

section used for setting the desiccants.

In order to investigate the effect of cooling of oyster shell, peltier element and photo voltaic cells were used to remove adsorption heat generation in the oyster shell.

The driving energy of peltier element is derived from solar. Fig. 4 is the result of inducing current for cooling effect. From Fig. 4, it is cleared that the cooling effect exists in this experiment and this effect is generally known phenomena among some references(Cooer and Alley, 1994; Benitez, 1993).
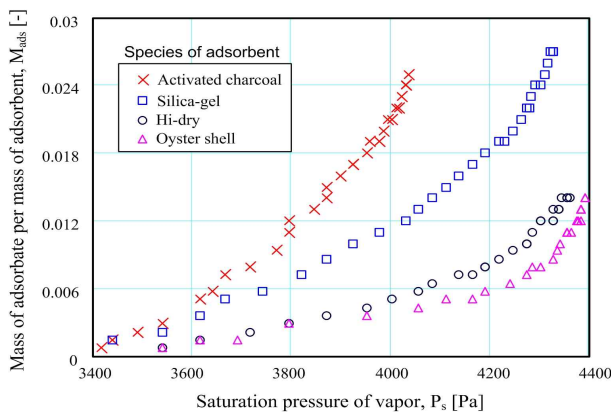

Fig. 4. Non-dimensional adsorption amount(Comparison of adsorbent species).

The increase in electric current induced into peltier element is effectively release the heat generation of adsorption. Consequently, the non-dimensional adsorption amount is increasing according to increase in electric current.

Fig. 4 indicates the results of adsorption experiments of silica-gel, activated charcoal, hi-dry(Japan made; commercially used), and oyster shell. From Fig. 4, it is clearly known that the highest value of non-dimensional adsorption amount exists at activated charcoal among any other materials.

This result would be explained that the specific surface area indicated in table 1 of activated charcoal is the highest value so the value of adsorption amount would increase with this proportion.

Fig. 5 is the results of induce current for cooling effect. From Fig. 5, it is clear that the cooling effect exists in this experiment and this effect is generally known phenomena among some references(Ono and Suzuki, 2005).

The increase in electric current induced into peltier elements is effectively release the heat generation of adsorption. Consequently, the non-dimensional adsorption

amount would increase with increase in electric current.

However, in the case of 0.8 [Amp] of induced current, the desorption process has been existed at the end region of experiment.
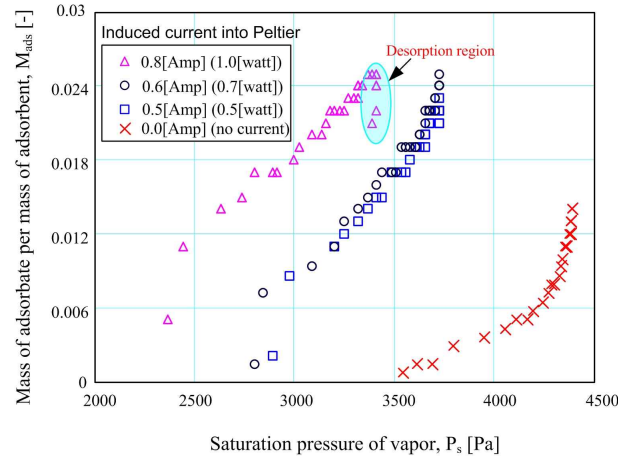

Fig. 5. Non-dimensional adsorption amount of oyster shell(Effect of induced current; so called cooling effect).

The reason of this phenomenon can be explained from the characteristic of peltier effect. The heating side of this experimental apparatus is composed with rectangular fins to release the heat generation of peltier element. According to the increase of induced current into peltier elements, the heat release fins can not release the adsorption heat sufficiently. Consequently, the heat of hot side of peltier is transferred into the cold side so the desorption process is occurred.

The typical types of adsorption isotherm lines are well known as Fig. 6(Kondo, et al, 2003). To compare with Fig. 6, the acquired results were re-plotted as Fig. 7 and Fig. 8.

From Fig. 7, oyster shell and other materials indicate the similar tendency with type III of Fig. 6. The type III is physical adsorption characteristic which is suitable for multi-layered molecular adsorption. And it is generally considered unfavourable for adsorption.

On the other hand, the data of adsorption amounts in Fig. 8 are increased with the increasing of induced current into peltier elements.

This means that the effect of adsorption heat release enhances the efficiency of adsorption. Consequently, the non-dimensional adsorption amount gradually approaches to the type II of Fig. 6 with increasing electric current. The type II is considered favourable for adsorption.
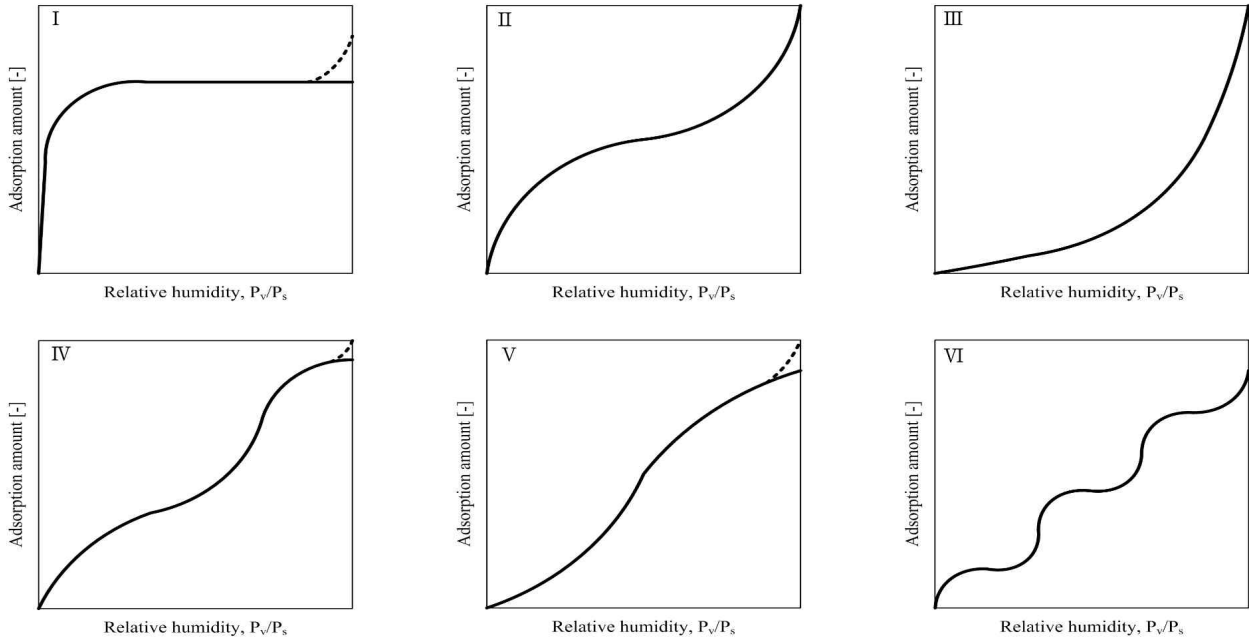
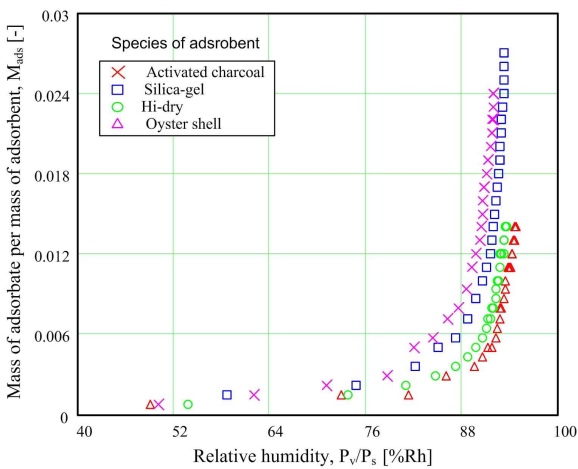Fig. 6. Typical types of adsorption isotherm lines(Kondo, et al., 2003).

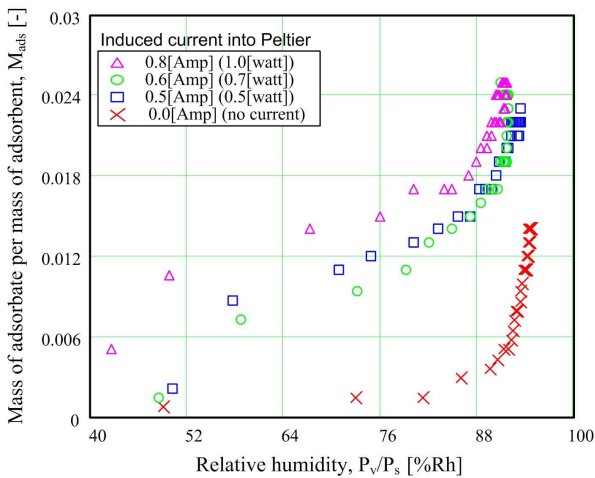Fig. 7. Non-dimensional adsorption amount of adsorbent.

Fig. 8. Effect of induced current into peltier elements.

3. Experimental Apparatus and Method for Dehumidifying Air Conditioning Chamber

Fig. 9 shows the schematic of the experimental apparatus and the details of peltier cooling duct. The experimental apparatus mainly consisted of a test section of dehumidifying air conditioning chamber and photo voltaic cells for supplying electricity.

In the chamber, the flow rate of circulating air is controlled by DC fans(12 V, 0.1 A, 3 EA) and the temperature of air is controlled by four peltier elements. Two of them are for latent heat releasing and others are for sensible heat releasing.

The T-type thermocouples were used for measuring the temperature of air and Anemometer was used for measuring the velocity of circulating air.

To check the variation of humidity in the chamber, the hygrometer was installed at the top of chamber and all of data were gathered every second.

4. Experimental Results and Discussions

Fig. 10 and 11 show the variations of saturation pressure and absolute humidity in chamber. In these graphs, the values of saturation pressure and absolute humidity decrease with increase in the mass of oyster shell. The increasing of mass of adsorbent means the increasing in surface area for adsorption so the amount of vapor in
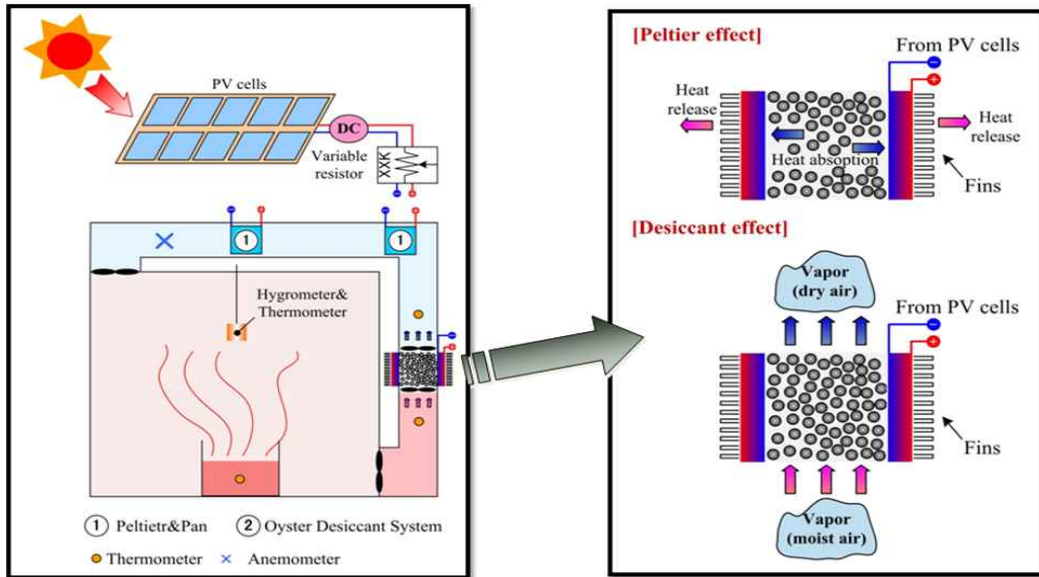
Fig. 9. Schematic diagram of experimental apparatus for dehumidifying air conditioning chamber.

chamber is decreased with increasing in mass of oyster shell. And the adsorption heat generation is effectively released by thermoelectric device so the capability of adsorption amount of oyster shell would be increased as shown in Fig. 5 Consequently, the saturation pressure of vapor is kept to the lower range. However, in the case of 0.8 [Amp] of induced current, desorption process has been existed at the end region of experiment. The reason of this phenomenon can be explained from the characteristic of peltier effect. According to the increase of induced current into peltier element the heat release fins can not release the adsorption heat sufficiently. Therefore, the heat of hot side of peltier is transferred into the cold side so desorption process is occurred.
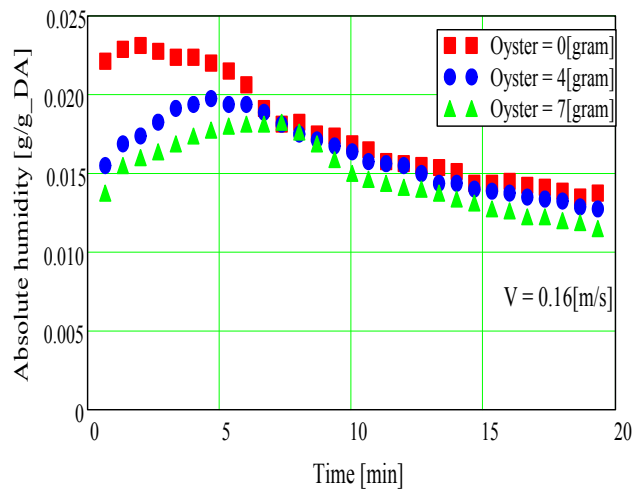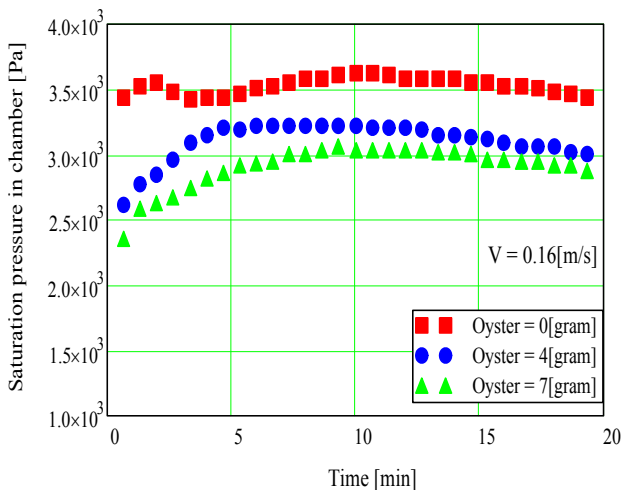

Fig. 11. Variation of absolute humidity.

Fig. 12 is the variation of room air temperature. As mentioned above, the peltier elements are working to cool the circulating air so the room air temperature is controlled. And also the oyster shell captures the moist of air so the latent heat load for this system reduces. For these reasons, the room air temperature decreases with increase in the mass of adsorbent(Oyster shell).

Using the results of Fig. 12, the enthalpy of moist air is calculated as followed equation. This equation is usually used for calculating the enthalpy of moist air. And Fig. 13 shows the calculated result of circulating room air enthalpy.

Fig. 10. Variation of saturation pressure.

$$h = Cp_{air} \cdot T_e + x \cdot \left(\gamma + Cp_{vap} \cdot T_e \right) \qquad (1)$$

Where, $Cpair$ = Specific heat of dry air [J/(kg·K)]

$Cpvap$ = Specific heat of vapour [J/(kg·K)]

T_e = Ambient temperature [K]

x = Absolute humidity [g/g_DA]

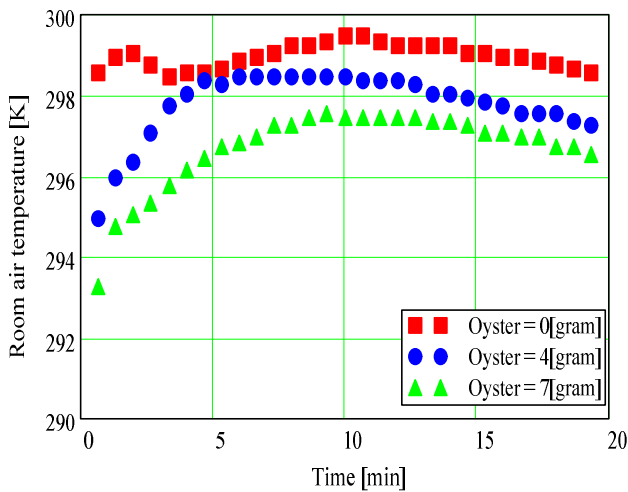γ = Latent heat of evaporation [J/kg]

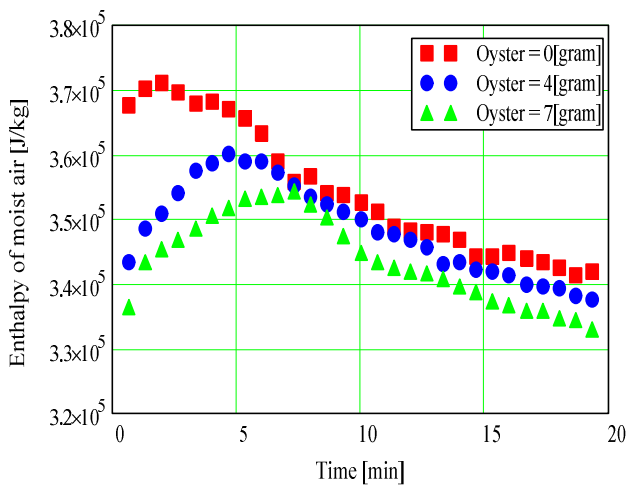Fig. 12. Variation of room air temperature.

Fig. 13. Enthalpy variation of moist air.

5. Conclusions

The probability of oyster shell desiccant cooling system driven by renewable energy of photo-voltaic effect was experimentally examined. This study has mainly performed in two parts of experiments. The one is for examine the adsorption characteristics of oyster shell and the other one is for adoption to the dehumidifying air-conditioning system. From this study, it is clarified that the oyster shell

has sufficient probability for using as desiccant in an air-conditioning system. Moreover, the heat releasing device would be attached in the system, the system based with oyster shell can be operated with high efficiency. The acquired main conclusions are summarized as follows.

1) Oyster shell has similar surface feature with other adsorption materials. This means that it can be used as desiccant material in a air-conditioning system.

2) As general characteristic behavior of adsorbent, all species of adsorbent used in this experiment showed that the non-dimensional adsorption amount have tendencies of increasing at higher saturation pressure of vapor.

3) Increase in electric current induced into peltier elements is effectively release the heat generation of adsorption. Consequently, the non-dimensional adsorption amount would increase with increase in electric current.

4) The non-dimensional adsorption amount of oyster shell gradually approaches to the type II(Typical adsorption isotherm line; favorable for adsorption) with increasing electric current.

5) It was found that the enthalpy of room air was kept lower range by the increase in mass of oyster shell.

Acknowledgement

References

[1] Aminabhavi, T. M. and H. G. Naik(1998), "Chemical compatibility study of geomembranes-sorption/ desorption, diffusion and swelling phenomena", Journal of hazardous materials, Vol. 60, No. 2, pp. 175-203.

[2] Benitez, J.(1993), "Process engineering and design for air pollution control", Englewood Cliffs, NJ: PRT Prentice Hall, vol. 331, pp. 414-421.

[3] Buonicore, A. J. and W. T. Davis(1992), "Air Pollution Engineering Manual", New York: Van Nostrand Reinhold, pp. 214-221.

[4] Cooer, C. D. and F. C. Alley(1994), "Air Pollution Control: A Design Approach", PROSPECT HEIGHTS, IL: Waveland Press, Inc., pp. 569-580.

[5] Dubinin, M. M.(1995), "The potential theory of

adsorption of gases and vapors for adsorbents with energetically non-uniform surfaces", Chemical Reviews, pp. 235-241.

[6] Kondo, Seiichi, Tatsuo Ishikawa and Ikuo Abe(2003), "Science of adsorption", Maruzen Publishers, Inc., pp. 28-30.

[7] Lee, S. h.(2000), "Environmental Protection and Ecological Ethics", The Korean Ethics Studies Association, Vol. 44, No. 1, pp. 65-82.

[8] Nevers, N. de(1995), "Air Pollution Control Engineering", New York: McGraw Hill, pp. 131-134.

[9] Noll, K. E., V. Gounaris and W. S. How(1992), "Adsorption Technology", Ann Arbor, MI: Lewis Publishers, Inc., pp. 142-147.

[10] Ono, Yoshio and Isao Suzuki(2005), "Science and application of adsorption", Koudannsya Publishers, Inc., pp. 19-20.

[11] Polanyi, M.(1932), "Theories of the adsorption of gases", A general survey and some additional remarks, Transactions of the Faraday Society, 28, pp. 316-331.