



Title	Study on Open and Closed Chemical Thermal Energy Storage Technology with Low-regeneration Temperature [an abstract of dissertation and a summary of dissertation review]
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Degree Grantor	北海道大学
Degree Name	博士(工学)
Dissertation Number	甲第11574号
Issue Date	2014-09-25
Doc URL	https://hdl.handle.net/2115/57497
Rights(URL)	https://creativecommons.org/licenses/by-nc-sa/2.1/jp/
Type	doctoral thesis
File Information	Liu_Hongz-hi_abstract.pdf, 論文内容の要旨



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 劉 洪芝

学 位 論 文 題 名

Study on Open and Closed Chemical Thermal Energy Storage Technology with Low-regeneration
Temperature
(開放式と密閉系の低温化学蓄熱に関する研究)

Large amount of low temperature industrial waste heat ($<100^{\circ}\text{C}$) is discharged to the atmosphere. On the other hand, the solar energy is also a kind of low temperature heat source. Therefore, low temperature ($<100^{\circ}\text{C}$) advanced heat recovery technology needs to be prompted to reduce fossil fuel consumption and the impact of utilizing fossil fuel energy on environment and to increase the proportion of utilize renewable energy in energy consumption sector. Solid-gas chemical thermal energy storage technology is one of the most important heat storage technologies to save fossil fuel, and encourage using renewable energies and reduce the emission of greenhouse gases to achieve a clean and sustainable energy society profitable for humankind due to plenty of advantages, such as high thermal energy storage density, small heat loss and potential to supply cooling and heating at the same time. However, the low heat and mass transfer problems of the chemical materials is one of the obstacles for developing chemical thermal energy storage technology. The low-regeneration temperature material should be developed to store low temperature industrial waste heat or solar energy. Another problem with chemical heat storage material would be the degradation of the material after several cycles use. Therefore, low-regeneration temperature material with high stability is expected to be developed, moreover, suitable chemical thermal energy storage systems are also hoped to be built and evaluated.

Chapter 1 introduces generally thermal energy storage technology especially the chemical thermal energy storage. Then the necessity of thermal energy storage and the current research situation related with chemical thermal energy storage technologies are reviewed. Finally, objective and scope of this dissertation are shown.

Chapter 2 solves the low heat and mass transfer property of a chemical thermal energy storage material for an open chemical thermal energy storage system by impregnating CaCl_2 into mesopores of Wakkanai Siliceous Shale (WSS), which was built into a honeycomb structure to ensure a large contact area and low pressure loss. The honeycomb structure thermal energy storage medium is installed in an open thermal energy storage system, and it can be regenerated at 80°C showing a high thermal energy storage density at the same time. Moreover, the composite mesoporous material has the advantage of a long duration time for supplying stable heat with a low heat loss.

In Chapter 3, in order to decide the best operational condition of the developed open thermal energy storage system in Chapter 2, a numerical model is created. The simulation results can approximately predict the experimental values. Using the simulation program, optimal operating conditions are selected as follows: $T_{a,in} = 25^{\circ}\text{C}$ or 30°C , $RH_{a,in} = 95\%$, $f_a = 3.0 \text{ m}^3/\text{h}$, $L = 20$ or 25 cm for a heat release duration of ten hours. A realistic application is proposed and simulated, which can supply

air with a temperature greater than 40°C for 14 hours, and can be regenerated within ten hours during the daytime. Using the thermal energy storage system, 51.3% of the exhaust heat generated by a kerosene-fueled blower can be recovered.

Chapter 4 develops a new composite material by impregnating 9.6 wt% LiCl into WSS in order to get a wider and lower regeneration temperature range. The WSS + 9.6 wt% LiCl shows the same sorption amount with WSS + 22.4 wt% CaCl₂, but The WSS + 9.6 wt% LiCl can be regenerated at 60°C, and it shows higher volumetric heat storage density than the WSS + 22.4 wt% CaCl₂ when the outlet and inlet air temperature difference is 20°C at the same regeneration temperature due to lower desorption activation energy. The maximum outlet air temperature flowing out of the WSS + 9.6 wt% LiCl is less affected by the humid air flow rate in heat release process due to higher sorption rate when the sorption amount is small. At last, the WSS + 9.6 wt% LiCl is stable when it is regenerated at 60°C during the tested hundreds of sorption/desorption cycles, which indicates that this material can be used for a rather long time.

Chapter 5 gives a basic research of the composite material impregnated with LiCl by determining the isobaric and isosteric sorption chart of the composite material/water working pair in a closed thermal energy storage system, specific heat, and activation energy for desorption. A small scale sorption air cooler by using the developed composite material is built, and a high inlet and outlet air temperature difference is observed due to the rapid evaporation of the water inside the evaporator. Because of this, a relatively high value of the specific cooling power and a high cooling COP are obtained from the experimental results, which indicates a good perspective of improving the performance of this developed sorption cooler.

Chapter 6 develops a larger scale closed chemical thermal energy storage lab-scale prototype using the developed composite material in Chapter 5.

In Chapter 7, several application proposals for both the developed open and closed chemical thermal energy storage systems are described.

In Chapter 8, conclusions are briefly summarized for each chapter.