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A Review on Open Sorption Thermal Energy Storage System Using $MgCl_2.6H_2O$

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Abstract *– In most recent couple of decades, Thermal Energy Storage (TES) has turned into the topic of most extreme significance in many engineering applications and has been demonstrated as the subject of great interest of research work. Sorption systems (adsorption or absorption) are reliant on a chemical processes and subsequently are also named as chemical heat storage. The Chemical Thermal Energy Storage (CTES) incorporates sorption and thermochemical systems. In sorption energy storage, heat is stored by dissociation reaction and is recovered in chemically reverse reaction. Sorption TES has high storage densities than other types of TES, in this way permitting huge amount of thermal energy to be stored by utilizing small amount of storage substances. Energy storage dependent on chemical reaction is especially reasonable for long term and short term storage applications, e.g., solar heat storage, daily waste heat storage, etc. Amid the storage duration, since the process includes no heat losses, storage is typically completed at surrounding temperatures. This paper reviews only the open sorption TES utilizing* $MgCl_2.6H_2O$ *salt hydrate with an interest in comparing different heat storage materials, latest advancements in materials, their characterization, their limitations and conceivable changes for their applications.*

INTRODUCTION

The sharp rise in requirement for energy, the ascent in the cost of fuel connected with the ever increased consumption of non renewable fossil fuels, and the constant increase in CO_2 discharges all require the improvement of more energy efficient procedures and a move from non-renewable energy sources to renewable energy sources.[1] In this sense, thermal energy storage and change (TESC) can improve the thermal energy effectiveness of a process by reusing the waste heat from industrial processes, solar power or different sources. Sensible, Latent and Thermochemical (sorption and chemical) heat storage methods are the main types of thermal energy storage strategies.[2][3] This paper concentrates just on sorption chemical heat energy storage. Sorption thermal energy storage is expressed as storage of heat energy for heating and cooling applications amid the prescribed time period. It is renewable energy system which serves to upscale the efficiency of existing system and making the energy accessible as when required. Sorption system is to be designed for a specific storage duration, temperature necessities, available space, storage capacity and heat losses.[4] Chemical sorption TES systems operates on reversible chemical reactions i.e. Thermochemical TES These are more efficient, compact, possesses higher energy storage densities and can be used for long and short term storage. It is based on chemically reverse reaction as: $C + Heat \leftrightarrow A + B$. where, C is the heat storage material which is stable chemical mixture of A and B. By providing heat to C, the substance A and the substance B are separated and are stored separately. The reaction happens in reverse order when A and B are united together and the substance C is regenerated thus releasing useful heat from TES system. The system capacity is calculated by the value of heat liberated during regeneration of C. As mentioned in above reaction, the substance A will be among the ammoniate, hydroxide, hydrate, chloride, etc. and B can be water, NH_3, hydrogen, etc. C is usually a solid or liquid (no restriction on phases) but A and B can be of any phase.[5] The TES includes following steps for energy storage and recovery. These steps/processes are elucidated in fig. 1. and are individually described. Charging process:- It is an endothermic process where the heat is taken from energy source like solar, waste heat or heat from fossil fuel. The heat energy supplied is used for dissociation of material C which equals to heat of reaction or enthalpy of formation. Thus, after dissociation, materials A and B are formed which are stored separately. The reaction is as follows: C + Heat → A + B

Storing process:- Material A and material B are separately stored after charging process. These materials are usually stored at ambient temperatures as there is almost no energy loss. The energy loss may be observed only during initial cooling after charging and material degradation.

Discharging process:- After the required interval of time when the energy is required, the materials A and B are combined together giving an exothermic reaction. Thus the stored heat is recovered by regenerating C again and the cycle can be repeated over several times. The reaction is as follows: A + B → C + Heat

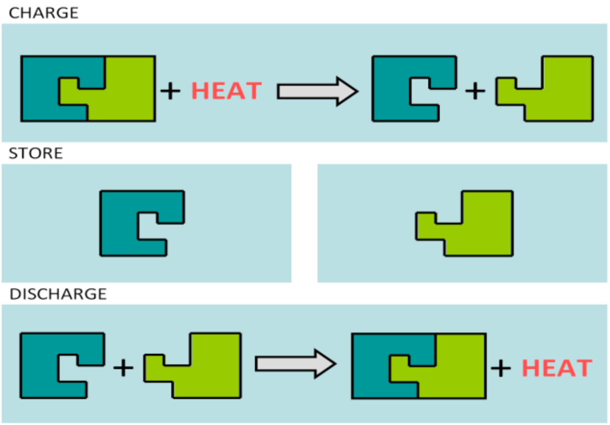

Fig.1- fig shows the working principle of Sorption Thermochemical TES system

LITERATURE REVIEWE

Cot-Goresetal,[6] used water as sorbate substance as it is abundantly available, non-toxic nature and environmentally safe. Hence, hydrophilic substances like $MgCl_2$, $CaCl_2$, LiBr, zeolite, silicagel, etc were used as sorbent substance for sorption applications. During charging, heat energy is stored by breaking water-sorbent bond by evaporating water from sorbent. Heat is recovered by recombining the water vapour and sorbent.

IRENA ETSAP,[7] thought about the storage capacity limit and temperature of sensible, latent and sorption TES systems. Hence, inferred that the sorption systems have higher storage densities. The related outcomes are shown in fig. no. 2. Material determination is a major step that altogether influences the execution of thermochemical storage systems process. Key components to be taken in account in selecting thermochemical material for a thermochemical storage system are as:- High storage density at the working conditions, low charging time, which brings about higher system effectiveness too, suitable accessibility, high thermal conductivity and high heat exchange rate from material to heat exchangers, which improves the efficiency of the storage system, environmentally agreeable, non toxic, non combustible (particularly in open loop systems); lower Global Warming Potential (GWP) and ozone Depletion Potential (ODP), non destructive, which enhances the life of components in thermochemical TES, low cost, good cyclic ability (reversibility with little degradation over huge quantities of cycles) and additionally thermally and chemically stable under working conditions (pressure and temperature), ability to be designed into a practical system (e.g., heat exchange qualities and flow properties), low temperature heat source required for the evaporation amid discharging period, good response rate, moderate working pressure limits; no excess pressure conditions, easy to handle and transport.

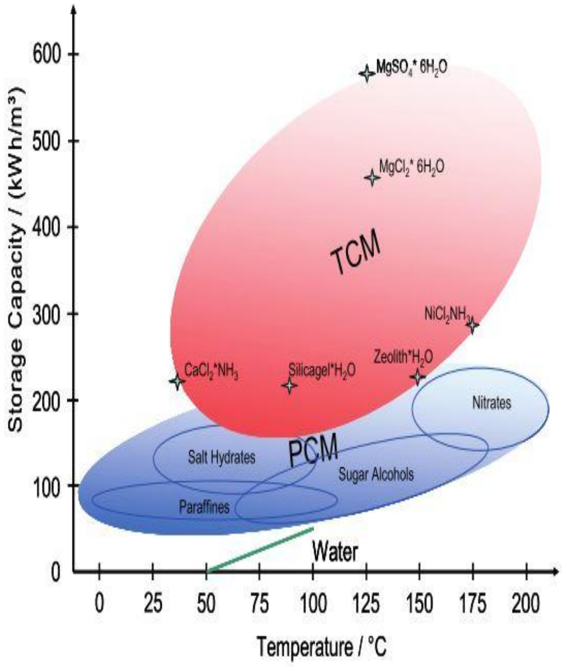

Fig.2 – fig shows the comparative of storage capacities of sensible, latent and thermochemical heat storages.

Material couples suitable for chemical heat storage: Table no.1 shows the different thermochemical materials and their operating characteristics.

Table-1-Performance comparison of different sorption materials.

Material	**Operating Conditions**	**Heat Released**	**Reference**
$MgSO_4.7H_2O \rightarrow MgSO_4 + 7.H_2O$	Charging→ 120-150 ^{0}C Discharging →120 ^{0}C	1533MJ/m^3 of $MgSO_4$	[8] [9]
$MgCl_2.6H_2O \rightarrow MgCl_2.2H_2O + 4H_2O$	Charging→ 115-130 ^{0}C Discharging →35 ^{0}C	2170.8MJ/m^3 of $MgCl_2.2H_2O$	[8]
$MgCl_2.6H_2O \rightarrow MgCl_2.H_2O + 5H_2O$	Charging→ 150 ^{0}C Discharging →30-50 ^{0}C	2001.2 MJ/m^3 of $MgCl_2.H_2O$	[8]
$CaCl_2.2H_2O \rightarrow CaCl_2.H_2O + H_2O$	Charging→ 95 ^{0}C Discharging →35 ^{0}C	720 MJ/m^3 of $CaCl_2.H_2O$	[8] [10]

Van Essen et. al.[11], Thermochemical sorption heat storage gives new chances to long time heat capacity, for example, seasonal heat storage. Ease materials have been distinguished that have adequately high storage density, can create adequate temperature increase to be utilized for heating purposes and have adequately fast kinetics to produce the estimated power. The chosen material, which is a composite based of $MgCl_2.6H_2O$ with a transporter material that was hydrated and got dried out in an open reactor system.

Ferchaud. C. et. al.[12] , presumed that $MgCl_2.6H_2O$ indicates fundamentally speedier response rates and higher hydration power output than sulphate materials, over continuous drying out and hydration cycles. This better thermal performance can be identified with more ideal lattice structure redesign (H-bonds, small cross section compaction) amid the reversible hydration/drying out process, which encourages quick response kinetics and may advance fast water vapour transport inside the material.

Zondag et. al.[13], directed trials utilizing $MgCl_2.6H_2O$ as safeguard material, because of its low cost, high heat storage density, non-toxic nature. An open reactor system was utilized on account of its less complex nature, economic development, long life and reliable quality. Pressure drop above the highest point of bed was seen because of the accumulation of a strong layer of sorbent material. This was due to over hydration. Consequently, a carrier material (cellulose) is utilized to neglect over hydration. To stay away from development of HCl vapours amid desorption, the maximum temperature was set to 130 ^oC Test results demonstrated 20 ^oC increase in temperature for hydration of 245 gm of $MgCl_2$, which is sufficiently reasonable for use of sorption TES system.

Zondag et al.[14], demonstrated that, at 12 mbar pressure over the bed, the lack of hydration of $MgCl_2.6H_2O$ gives temperature increase of 20 ^oC. This guarantees applicability of this TCM material for regular heat storage, tap water and space heating. By up scaling of the reactor and utilizing easy open reactor system, the craved performance was seen. Moreover, the vast storage capacity of TCM was seen on hydration of 3.6 kg of $MgCl_2.6H_2O$ composite when hot air was passed for 24 hours and the bed was not completely hydrated.

Gaeini, M.et. al.[15], outlined and tried a setup to recreate the thermochemical long term heat storage, keeping in mind the end goal to research the ability of the system for giving hot tap water. Execution of the system is analyzed in hydration and dehydration analyses. In hydration, the discharged energy in the reactor is exchanged by the air flow to the water vessel to warm up water. The performance of the system is enhanced by an aerial heat exchanger for getting the heat recuperation; the rest of the heat in the air stream after the water vessel is utilized to preheat the incoming flow to the reactor. The maximum achieved temperatures in the water vessel are around 36 ^oC and 44 °C for hydration without and with the heat recuperation, individually. Since the required temperature for hot tap water is 65 °C, the execution of the system needs more change. Making the system conservative and very much protected is important.

Johannes et. al.[16], designed a powerful sorption system for building application. Three parameters were examined viz. air flow rates, dehydration temperatures and relative humidity amid hydration. The principle results were:

- Lower the dehydration temperature the lower the energy however the maximum discharged power continues as before.
- Lower the relative humidity amid hydration, lower is the maximum discharged power.
- The air flow rate reduction causes to a decrease of the maximum discharged power with same stored energy.

Benoit Michel et. al[17], inferred that for the open system, the mass exchange is the fundamental impediment and the hydration rate can be enhanced by following up on the bed penetrability: multiplying the porousness prompts to a half response time. The normal particular power is more for open system than closed systems. Likewise, the open thermochemical reactor, which presents specialized points of interest (less complexity, bring down costs, etc.) is a potential approach to actualize thermochemeical process as a long term heat storage.

Michel et. al.[18], focused on a working model with moist air. Additionally, the mass flow rate is a basic control parameter however it can just direct the response control provided by the thermochemical reactor. Then again, controlling the moist air at reactor inlet is significant to directing both reactor features: its thermal power and the moist air outlet temperature. They showed the feasibility of a long time storage system including a thermochemical process working with moist air, and has empowered the recognizable proof of effective and basic approaches to control the thermal power yield so as to take care of user demand.

From the above literature survey, $MgCl_2.6H_2O$ is found to me most appropriate TCM material for the Sorption TES in open reactor system.

CONCLUSION

A review of thermochemical open sorption TES using $MgCl_2.6H_2O$, has been presented. Principles of sorption TES and modern advancements have been reported. $MgCl_2.6H_2O$ was selected as it has high heat storage capacity, non-toxicity, easy availability, low cost and ease of handling. The possibility of achieving more compact systems, little energy losses during the storing operation and higher energy densities compared to other types of TES are the most prominent advantages of thermochemical sorption TES systems. The thermochemical material (TCM) is a critical component of such systems. The cyclic behavior and degradation of thermochemical materials, as well as their cost, availability, durability and energy density, are important parameters affecting the selection of a thermochemscal material. Further research is needed to improve understanding of the scientific and engineering characteristics of thermochemical TES systems and to help improve various aspects relating to the performance and implementation of these systems as well as on design factors, safety, size and efficiency, installation, maintenance and economics for thermochemical TES systems.

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