Overview of latent heat and thermochemical heat storage

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Solar energy or industrial waste heat is usually discontinuous. A stable and efficient heat storage system can improve the efficiency of industrial waste heat utilization.
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Low-cost PCM

NaNO$_3$-Ca(NO$_3$)$_2$ binary eutectic salt

- NaNO$_3$:Ca(NO$_3$)$_2$ is 7:3 (mol%), $T_m=220^\circ$C;
- High energy density (135.8 kJ/kg);
- Low cost (10.84 $/kWh, Solar salt 14.09 $/kWh);
- Low corrosivity, high stability.

NaNO$_3$-Ca(NO$_3$)$_2$-KNO$_3$ ternary salt

- Ca:Na:K is 32:24:44 (wt%), $T_m$~90°C, $L=67$ J/g;
- Low cost, high stability, moderate viscosity;
- Used as heat transfer fluid and heat storage media.


Latent heat storage

Heat transfer enhancement

Techniques

Fin

Metal foam

Expanded graphite

Metal particle

Heat pipe

Nanoparticle
Latent heat storage

Experimental studies on the heat transfer enhancement of metal foam and expanded graphite.

- The effect of metal foam is better than that of expanded graphite.
- The effect of pore density is more significant than that of porosity.

Latent heat storage

Metallic PCMs—high-temperature storage materials

- Al-Si Alloy

- Melting temperature: 576~580°C
- High energy storage density: 430~450 kJ/kg for AlSi12
- High thermal conductivity
  - Severely corrosive to common steels, but compatible with some ceramic materials: Al₂O₃ and AlN.

Optimization design of cascaded latent thermal storage （conceptual principle for integration and optimization）

For high temperature heat source, thermal efficiency with the single-stage storage method is low.

Solution: Storing thermal energy with cascaded storage system.

Theoretical and experimental researches on cascaded thermal storage and the optimization.

Schematic diagram for cascaded storage
Overview of the experimental cascaded latent heat storage system

- The storage efficiencies of energy, exergy and entransy increase with stage number.
- Storage temperatures and heat transfer performance play different roles in the storage efficiencies of energy, exergy and entransy.

DSC test of the PCMs
Thermochemical heat storage stores thermal energy in the form of chemical bonds. It is advantageous in high energy density (over 1,000 kJ/kg), low cost and ability to long-term thermal storage.

Advantages of thermochemical heat storage

Energy storage densities for different storage methods

Source: Bales C, In: Proceedings of DANVAK seminar, DANVAK seminar, November 2006
The results of energy barrier indicate that the dehydration process for Li-doped Ca(OH)$_2$ can be accomplished more easily.

The TG results show that the dehydration process has greatly changed after doping Li ion.
Thermochemical heat storage

Heat transfer

- The microstructures of the powders can be accurately reconstructed through Random Sphere-like Particle Packing (RSPP) method;
- ETCs of TCMs are changing when the reaction is proceeding.

The hydration extent of MgO decreases with the increase of dehydration temperature;

The MgO particles agglomerate with each other at high temperatures.

This study aims to analyse the effects of CO₂ on heat storage materials.
**Thermochemical heat storage**

**CO₂ effect on thermochemical heat storage materials**

**In heat storage process**

- CO₂ effect on Mg(OH)₂/MgO systems can be negligible in heat storage/release processes;
- CO₂ has a slight effect in heat storage process for Ca(OH)₂/CaO, but it could be a problem in heat release process.

Thermochemical heat storage systems

—investigate the reaction, heat and mass transfer inside the reactors for the optimization of the thermochemical heat storage systems.

Fixed bed Ca(OH)$_2$/CaO heat storage system

Fluidized bed Mg(OH)$_2$/MgO heat storage system
Thermochemical heat storage

CaO/Ca(OH)$_2$ fixed bed reactor

- The heat storage rate increases with the wall temperature;
- The heat storage rate is enhanced when Li-doped Ca(OH)$_2$ is adopted;
- The reaction efficiency can be enhanced with the vapor pressure.

Heat storage process of Ca(OH)$_2$ at different wall temperatures

Comparison of the heat storage process between pure Ca(OH)$_2$ and Li-doped Ca(OH)$_2$

Heat release process under different vapor pressures

Technical barriers for heat storage techniques

- Cyclic stability of heat storage systems needs to be verified and promoted.

- Compatibility between PCMs and container-wall materials should be paid much attention.

- Thermal resistance due to PCM volume variation in the phase change process may lead to hot spots (packaging).

- Heat transfer should be carefully controlled to match chemical reaction rates.

Outlook
Thank you for your attention!

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