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ELECTRICAL CHARGING FOR ENHANCED EFFICIENCY OF THERMOCHEMICAL ENERGY STORAGE

Summary

Thermochemical storage systems are gaining attention as a promising solution to address the intermittency of renewable energy, particularly in Europe's residential sector, where heating demands a substantial share of total energy consumption. This work focuses on a novel thermochemical energy storage system integrating heat pump functionality during charging, featuring two alternative charging modes for salt hydrate based systems: First, electrical charging via a resistive heater. Second, an alternative mode based on mechanical vapor compression, where dehydration-generated vapor is extracted, recompressed, and condensed to reuse its heat for the endothermic reaction—reducing reliance on ambient temperatures. Both concepts are introduced by an analytical study focusing on COP followed by first experimental results and the design of the proof of concept setup.

Keywords: thermochemical energy storage, heat pump functionality, s

Field of application for the findings: Thermal energy storage

Addressed audience: Engineers looking into new ideas for thermal energy storage

1. Introduction

The energy transition from fossil fuels to renewable energy sources increases the need for storage systems capable of compensating for the inherent intermittency of these sources, especially in the residential sector, where the energy demand for heating represents a significant share of total energy consumption in Europe. In this context, thermochemical storage systems emerge as a promising alternative. The current work focuses on the development of a flexible thermochemical storage system for temperature regimes <80 °C that can be easily adapted to varying operating conditions (different countries) as well as to variable charging conditions. Thus, one core goal of the project is the development of a flexible system which cannot only be charged by thermal energy, but also in a very efficient way using electrical energy from renewable sources reaching COPs>1.

2. Thermochemical energy storage with COP>1

For any energy storage system, the storage efficiency is defined as the ratio between the useful energy released during discharge and the energy supplied to the system. This value can by definition not exceed values of 1. However, in thermochemical energy storage systems based on the reaction of salt-hydrates with water, the stored energy can be split into two: the energy corresponding to the reaction enthalpy as well as to the energy corresponding to evaporation and condensation of the water. Thus, in case the system boundaries can be extended to a clever gas management, system efficiencies exceeding 1 can be reached. E.g., when the heat of evaporation is not required as the system can be discharged using moist air. In this case, it is rather appropriate to not use the term efficiency, but to use the coefficient of performance (COP).

$$COP = \frac{Q_{\text{useful}}}{E_{\text{supplied}}} \qquad \text{(eq. 1)}$$

The present work actually focuses on the increase of the overall COP of the thermochemical energy storage by implementing two different methods for electrical charging, while the basic assumptions is still related to a corresponding discharging process using moist air. These two different methods can be deduced from the concept of the thermochemical reaction, which follows a temperature-pressure equilibrium: to promote the dehydration reaction – which relates to the charging process - it is necessary to establish a driving force to initiate the reaction. Method of charging I ("push" concept) increases the system temperature by providing thermal energy at an elevated temperature, thereby pushing the water vapor out of the salt. In contrast, method of charging II ("pull" concept) pulls the water vapor outward by reducing the system pressure, which also shifts the operating conditions away from equilibrium state.

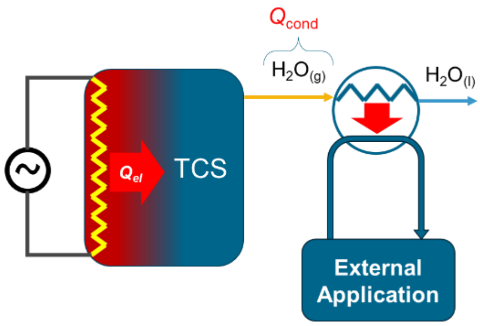

Fig. 1: Method I (push) to charge a thermochemical system using electrical energy.

Method I (push) is illustrated in Figure1. The system is charged using electrical energy while the water vapor released from the thermochemical dehydration is applied externally. Thus, the latent heat of condensation of this vapor is used as useful energy. For this configuration, the resulting COP remains essentially constant for a selected salt hydrate materials and is independent of the charging temperature. For K_2CO_3-sesquihydrate as a reference material (Aarts et al, 2022), the theoretical value for this method can be calculated to COP = 1.6.

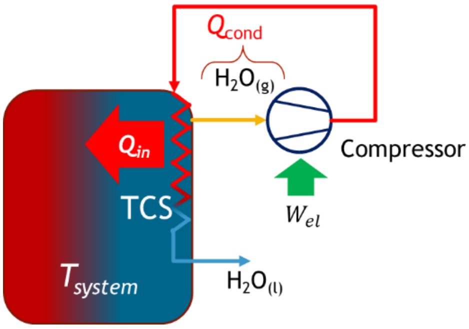

Fig. 2:Method II (pull) to charge a thermochemical system using electrical energy.

Method II is illustrated in Figure 2. In this case, the system is also electrically driven, but in this case, the gas is actually pulled out of the material. Then, the temperature and pressure of the water vapor are increased through mechanical vapor recompression, and the latent heat of condensation is internally recovered by an indirect heat transfer to the thermochemical material. In this case, the COP increases with increasing charging temperature, as the effort of the compressor is based on the compression ratio, which decrease with increasing temperature. For the reference material, K_2CO_3-sesquihydrate a maximum value of 2.7 can be calculated at 20 °C. Thus, it is obvious that this method for charging can be very promising for thermochemical systems in the framework of electricity surplus for storage of thermal energy.

3. Conclusion

The contribution will present the detailed analytical study of the calculations for the efficiency regarding the different charging methods. Furthermore, preliminary experimental results will indicate the future potential of this thermochemical energy storage system.

4. References

Aarts, J., de Jong, S., Cotti, M., Donkers, P., Fischer, H., Adan, O., Huinink, H., 2022. Diffusion limited hydration kinetics of millimeter sized salt hydrate particles for thermochemical heat storage, J. of Energy Storage, 47