Thermochemical Seasonal Heat Storage for the Built Environment

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Introduction
Replacing the use of fossil fuel by solar energy, as one of the most promising sustainable energy sources, is of high interest, because of climate change and depletion of fossil resources. However, to reach high solar fractions and to overcome the mismatch between supply and demand of solar heat, storage of solar energy is necessary. A reliable method for long term heat storage is to use thermochemical materials, TCMs; since it offers higher energy density and almost no heat loss, compare to the conventional methods. The process is based on a reversible sorption-desorption reaction, which is exothermic in one direction and endothermic in the reverse direction.

Multi-level approach
The goal of this project is to build a prototype in large scale as a proof of principle for the thermochemical heat storage. In order to make such a system work, the research has to be done, both experimentally and numerically, on three levels:

1) Material investigation needs to be done in order to find an optimum material which has a high energy density, fast Kinetics correspondent to the required power in the house and stability during charging-discharging cycles. These can be investigated by thermal analysis of TCMs, such as Thermal Gravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC).

2) Reactor design should be done based on the heat and mass transfer phenomena; it can be studied by doing experiments in the reactor setup and by modeling. In the reactor setup, the flow is prepared in the first section to have a controlled flow rate, temperature and humidity. The controlled moist airflow is introduced to the material inside the reactor and temperature profiles and humidity are measured. The reactor setup is also used for performing final tests on the materials to check their performances at a larger scale.

3) System improvement should increase the heat recovery and decrease the heat loss in the system. A system setup is built in the lab, consists of a reactor and three other major components: humidifier, water vessel and air-to-air heat exchanger.

Modeling
The numerical studies are being followed on all the three levels. The reactor model can be described as follow:

**mass:**
\[ \frac{d\rho}{dt} + \rho \nabla \cdot \mathbf{u} = -
\]

**heat:**
\[ \rho \frac{dE}{dt} = \rho Cp_{p} \mathbf{u} \cdot \nabla T - \nabla \cdot (\kappa \nabla T) + \frac{\partial}{\partial t} \int_{0}^{t} (E_{R}(T) + H) \, dt + Q_{	ext{loss}} \]

**kinetics (Linear Driving Force):**
\[ \frac{d\theta}{dt} = \frac{k_{0} \exp(-\frac{q_{\text{eq}}}{T})}{h} \]

**equilibrium:**
\[ q_{\text{eq}} = \frac{b T^n}{1 + b T^n} \]

Preliminary results
By comparing numerical and experimental results, it can be seen that the measured temperatures are lower than calculated ones. It is because that the heat loss in the model is assumed to be zero, in order to find the highest achievable temperature. The maximum temperature can be increased by improving the heat recovery as well.

Conclusion and outlook
The research is carrying out on material, reactor and system levels, experimentally and numerically. The kinetics of the optimum thermochemical material will be studied and employed in the reactor model. The reactor model, which includes mass and heat transfer equations, will be used for optimal design of the reactor. Efficiencies of different components in the system should be improved, and integrated by the final reactor as a system. On the system level, increasing heat recovery and decreasing heat loss are important.