THERMAL UPGRADE OF PROCESS WASTE HEAT WITH THERMOCHEMICAL ENERGY STORAGE

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Background

Increasing process efficiencies is one important path on the way to reduce overall CO_2 emissions. One interesting possibility in this context is to recycle low grade thermal energy. This low grade heat is currently mainly a waste product since the thermal energy might be required at another time, location and/or at higher temperatures. Therefore, in order to reutilize low grade waste heat not only thermal energy storage is necessary but also a thermal upgrade to higher temperatures. Both can be realized by thermochemical energy storages based on reversible gas-solid reactions.

Aims

The focus of this work is to demonstrate experimentally and understand in detail the possibilities, limitations and constraints of the thermal upgrade of low grade waste heat by thermochemical processes. This demands detailed investigations of thermochemical and thermophysical material properties, the development of a simulation tool as well as its validation with experimental analysis in lab-scale.

Methods

For the relevant temperature range of 100-200°C a screening of possible reaction systems was performed that identified $CaCl_2/H_2O$ as suitable system. The thermophysical properties such as permeability, thermal conductivity and particle size distribution of the material as well as thermodynamics and kinetics of the reaction have been investigated based on various measurement techniques such as thermogravimetric analysis. A test bench has been designed and brought into operation in order to investigate the thermochemical reactor in lab-scale (500 g storage material, 400 kJ storage capacity). Additionally, a detailed model was developed and validated in order to understand the heat and mass transfer within the reactor and to be able to optimize the charging and discharging process of the thermochemical storage.

Results

Good reversibility and cycling stability as well as sufficient rates of reaction were found for the gas-solid hydration reaction of $CaCl_2$:

$$CaCl_2 \cdot 2H_2O \rightleftharpoons CaCl_2 + 2H_2O$$

The reaction includes intermediate hydration steps that have a big influence on the temperature distribution inside the reactor which was identified by simulation and has been confirmed by the experimental investigation. Charging and discharging cycles were performed analyzing heat fluxes and showing experimental proof-of-principle for thermal upgrade. Based on these experimental results, an optimized reactor design was developed in order to increase heat and mass transfer and ensure high power densities.

Summary

The presentation will introduce the operation principle of the heat transformer based on thermochemical reactions and will focus on the results of the experimental investigation and their simulation supported analysis including advantages and limitations of this technology.