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INNOVATIVE HEAT TRANSFORMATION BASED ON THERMOCHEMICAL SYSTEMS USING SALT HYDRATES

Summary

Thermochemical energy storage is known for its high energy density and the capacity to store thermal energy over extended periods with minimal heat losses. Such storage systems can be used for heat transformation and thus upgrade waste heat. A promising application of this principle is the gas-solid reaction between strontium bromide and water vapour:

$$SrBr_{2(s)} + H_2O_{(g)} \rightleftharpoons SrBr_2\cdot H_2O_{(s)} + \Delta_R H$$

This reversible reaction has a specific energy density of 291 kJ/kg $SrBr_2$.

In this work, two reactor prototypes based on the $SrBr_2/H_2O$ working pair are compared in terms of their thermal performance, power density and efficiency.

Keywords: Industrial waste heat recovery, thermochemical gas-solid reaction, $SrBr_2(s)$-$H_2O(g)$; heat transformation

1. Introduction

The pursuit of zero-net carbon economy requires the expansion of renewable energy capacity and the enhancement of energy efficiency within industry. Notably, around 50% of global final energy consumption stems from heat production—predominantly in industrial processes and building heating applications [1]. In Europe, the industrial waste heat totalled approximately 300 TWh in 2015, with a significant portion—about 30%—operating within the temperature range of 100–200 °C [2].

Therefore, thermochemical gas-solid reactions emerge as a promising alternative for waste heat recovery or thermal upgrade. These reactions are pressure-dependent, enabling them to be charged at lower temperatures and discharged at higher ones.

An interesting example is the $SrBr_2/H_2O$ thermochemical system, which is demonstrated stable after multiple thermal cycles [3]. This work presents and compares two experimental prototypes of a thermochemical system employing the $SrBr_2/H_2O_{(g)}$ reaction, designed to harness industrial waste heat in the range of 180 to 260 °C

2. Current work

Two reactors at lab scale are developed for the thermal cycling of $SrBr_{2.}$

The first reactor design consists of four cells filled with the salt hydrate. Each cell is comprised of a central tube for the flow of the heat transfer fluid (HTF) and an axially extruded aluminium fin. A stainless-steel mesh filter layer is used to help contain the material in place (Fig. 1). The nominal power of this prototype is 5 kW.

The second design corresponds to a 2-kW finned tube reactor. It consists of a series of 8 tubes (where the HTF flows) and multiple fins are placed across them. The material occupies the void volume between the fins and tubes and is contained by means of a frame and two stained-steel mesh filter layers.

The reactors are contained in a cylindrical steel vessel connected to a test rig, which consists of two process thermostats, evaporator/condenser unit (E/C unit), multiple valves and a vacuum pump (Fig. 2). In this test facility, once the water vapor pressure is adjusted in the E/C units, it streams to or from the reactor and through the mesh filters that contain the reactive material. The heat of the reaction is supplied or collected by the HTF that is controlled by the process thermostats.

The cycle stability in the reaction of $SrBr_2$ with water vapor is verified through multiple de-/ rehydration experiments carried out in both prototypes.

It is shown through the experiments that a heat source at 180 °C can be upgraded to 280 °C. Such heat source temperature lays in the range of industrial waste heat (e.g. petrochemical) [4]. In addition, other applications of upgrading heat produced by renewable energy sources (e.g. solar collectors) are explored.

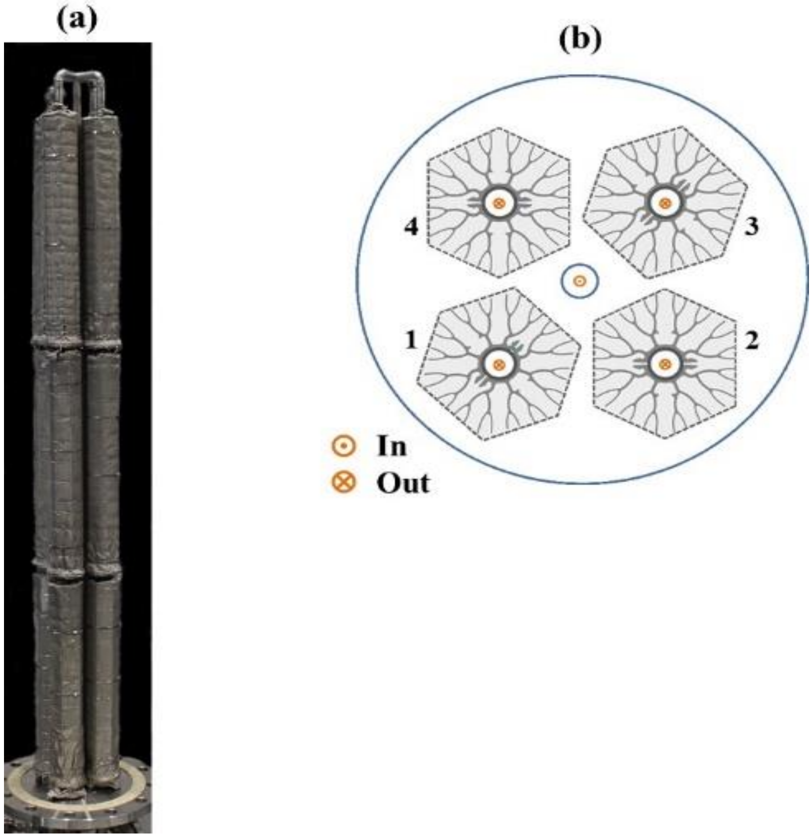

Fig. 1: (a) Reactor design for 5 kW thermal power. (b) Overhead view of the reactor with the 4 cells containing SrBr2 and the inlet and outlet of the HTF.

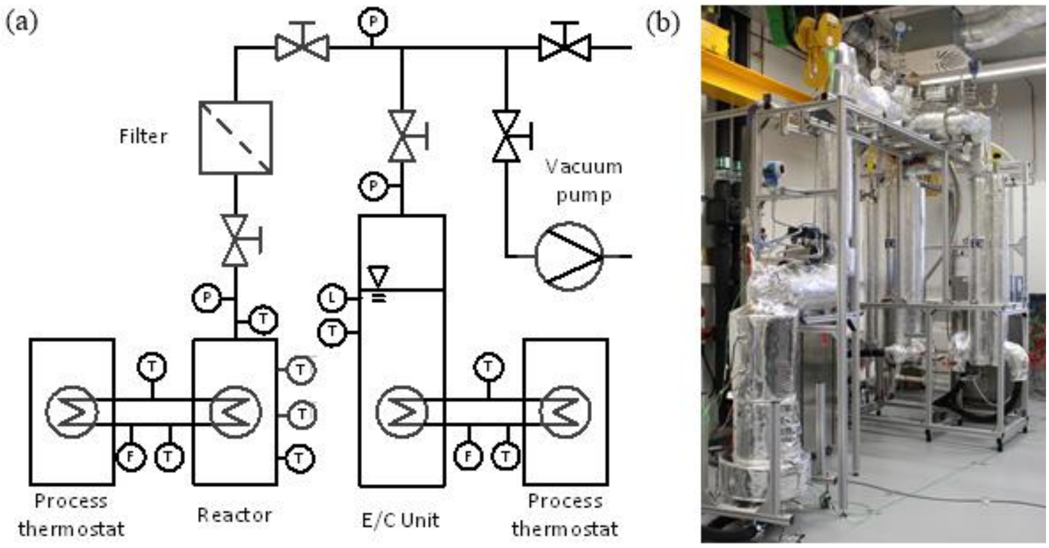

Fig. 2: (a) Diagram of the reactor integrated in the test rig. (b) Test facility for heat transformation at DLR.

4. References

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