Summary

Using thermochemical storage based on water absorption/desorption in a fluid with high volumetric energy density liquid like aqueous sodium hydroxide (NaOH-H₂O) is an effective method for developing seasonal thermal energy storage. For the desorption process step, a high renewable energy fraction can be reached by using solar collectors to convert solar radiation to heat in summer. The heat and mass exchangers are the core components from the reaction zone in this Liquid Sorption Energy Storage Concept. Their efficiency is influenced by the residence time of the fluid in the water vapour and the fluid surface wetting behaviour. This behaviour strongly depends on the wetted surface characteristics and on thermo-physical properties of sodium lye, especially the high surface tension. An improved wetting of the concentrated NaOH 50 wt% was achieved by modifying the surface chemistry (use of surfactants) and roughness (mechanical texturing).

Keywords: seasonal thermal energy storage, aqueous sodium lye, surface wetting, surfactant, surface texturing

1. Introduction

Almost half of the final energy demand in Europe is needed for heating and cooling applications. An important percent can be supplied from sustainable heat sources like waste heat or renewables. However, the energy production is sometimes out of sync with the energy demand. Seasonal heat storage/long-term storage of heat makes the energy available when it is needed. Moreover, heat storage is very advantageous when stand-alone systems are involved and when the security of supply is required.

Current research is focused on compact thermal energy storage technologies with high energy density like phase change materials (PCM) and thermochemical materials (TCM) or sorption processes – concepts followed in the European financed COMTES project (Daguenet-Frick et al., 2015). Although considerable efforts were made to find and improve thermal energy storage materials (e.g. in the framework of the IEA joint Task/Annex 42/29), the storage systems are still at lower technology readiness levels.

Using thermochemical storage based on water absorption/desorption in a high volumetric energy density fluid like aqueous sodium hydroxide (NaOH-H₂O) is an effective method for developing seasonal thermal energy storage (Cabeza, 2015). But the challenges lie in tackling the process engineering to transfer the materials thermo-physical properties (Daguenet-Frick et al., 2014; Fumey et al., 2015; Olsson et al., 1997) to a running system with the expected performance.

In this paper, an absorption/desorption unit working with sodium hydroxide and water is presented. The heat and mass exchangers are the core components from the reaction zone in this Liquid Sorption Energy Storage Concept. In the sorption process of water in sodium hydroxide (NaOH), the efficiency is strongly influenced by the fluid surface wetting. The focus of this paper is about methods to improve the surface wetting like surface modifications (structuring, use of metal foams) and fluid properties tuning (use of surfactants).

2. Experimental part

Flat porous metal foams (Fraunhofer-IFAM, Dresden) and different tubes with a flat surface or structured (with horizontal, perpendicular or cross grooves) made from stainless steel 1.4404 were used. Prior to the surface wetting experiments the samples were first cleaned (washed) with demineralized water and then with ethanol. To avoid carbonisation of the sodium lye with CO₂ from the air, experiments were performed into a glove bag (ca. 94x94x64 cm) filled with N₂. The N₂ 4.5 (purity ≥99.995%) functions as the inert gas.

The following chemicals were used: thermal fluid to be used in the heat and mass exchanger: sodium...
hydroxide, 50 wt% in H₂O (Sigma Aldrich), wetting agent: dihexyl sulfo succinate sodium salt (DHSS, (Sigma Aldrich), TRITON™ QS-1 (DOW), demineralized water and ethanol (technical).

3. Results and discussions

The tube bundle falling film concept was used for developing the heat and mass transfer unit due to the simple design, low costs and high heat transfer rates. Methods for improving the tube bundle surface wetting with concentrated NaOH-solution (50 wt%) and increasing the residence time of the lye in the vapour phase were analysed.

Wetting can be improved by modifying the liquid’s properties or by changing the solid surface. For the first approach, anionic surfactants like dihexyl sulfo succinate sodium salt or polyether sulfate were investigated. Experiments have shown that this is an efficient method for decreasing the solution surface tension, the contact angle and thus for improving the wetting of sodium lye. Surfactants can also be used in the evaporator unit to decrease the surface tension of water. The stability of these surfactant solutions is critical and investigations were performed in different conditions specific to the running system (e.g. temperature, high NaOH concentration).

For the second category, three mechanisms are likely improve the wetting: physical bonding (e.g. van der Waals and hydrogen bridges), chemical (ionic, atomic or metallic bonds) or mechanical. A better wetting is promoted when a large surface area is in contact with the liquid. Higher surface area was obtained by varying the mechanical texturing and by using metal foams. The development of the structured surfaces and/or metal foams enhances the heat transfer and thus reduces the size of absorber unit.

4. References


