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SolSpaces – Testing and performance analysis of a segmented sorption store for solar thermal space heating

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Abstract

An entirely solar based supply of heat for energy efficient buildings is the motivation for the activities within the research project SolSpaces. A solar heating system, including a sorption store for seasonal energy storage, has been developed to approach this objective. Sorption processes are well suited for long term energy storage, due to the quasi loss free storage of energy and the high energy storage density, compared to water stores. However, large sorption stores go along with some kind of challenges concerning the efficient supply of the stored heat. A new sorption store, subdivided into several segments, has been developed to meet the requirements for an efficient heat supply despite the relatively large size of the store. The segmentation leads to an improved operation behaviour. The segmented sorption store has been built up in full-scale in a research building for testing and demonstration. Experimental investigations are carried out to analyse the achievable temperature lift and charging and discharging power and to demonstrate the thermal performance of the store. Key parameters, such as energy storage density, will be determined. In this paper, the solar heating concept will be presented, focussing on the segmented sorption store. The design of the sorption store will be explained, experimental results and the operation behaviour will be shown and the performance will be discussed.

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Keywords: thermochemical energy storage; adsorption; seasonal energy storage; segmented sorption store; solar heating; high solar fraction

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1. Introduction

This day and age, when fluctuating energy sources increasingly contribute to the energy supply, the need for electrical and thermal energy stores, for industry and transport as well as for residential applications, is rarely controversial. In the field of residential buildings, thermal energy represents by far the major part of the energy consumption. To supply a buildings demand for thermal energy completely on a solar basis, seasonal thermal energy storage can serve as a promising approach. However, seasonal thermal energy stores are still rare. Commonly used water stores suffer from thermal losses and rather low energy storage density. In contrast, energy storage based on sorption processes offers a high energy storage density and an almost loss free storage over an arbitrary period of time. Therefore, sorption stores are well suited for long term energy storage and hence have been under wide investigation in recent years. Still, for large stores it is challenging to effectively provide the stored energy when needed. Against this background, a new design of sorption store, subdivided into several segments, has been developed providing an improved operation behaviour.

A solar heating system, including the segmented sorption store, has been installed in a research building for testing and demonstration. This building, manufactured by the prefabricated houses company SchwörerHaus KG, was completely prefabricated, delivered by truck and built up close to the Institute for Thermodynamics and Thermal Engineering. The living space amounts to 43 m^2, divided into three rooms: living room, bathroom and bedroom. The latter is used as a technical room within the project, containing the devices for space heating and hot water heating. The building is equipped with an air ventilation system that is used for space heating.

The heating demand of the SolSpaces building has been measured during a one year monitoring in the first year after the buildings setup. During this time it was still equipped with conventional heating devices (i.e. heat pump and electrical backup heating). The space heating demand of the uninhabited building without heat recovery is 4000 kWh [7]. Due to its dimensions, which lead to a rather large surface-to-volume ratio, the specific heating demand of the SolSpaces building is relatively high compared to lager buildings with the same insulation standard. This implies that the new solar heating system can be tested in the SolSpaces building and could subsequently be applied to lager buildings with similar heating demand. This is consistent with the overall objective of the research project: to approach an entirely solar based heat supply of energy efficient buildings.

Nomenclature

c_{p}	heat capacity
d_p	particle diameter
ε	porosity
I_{glob}	global solar radiation
k_1, k_2	constants for ergun equation
L	flow path
$\dot{m}_{\mathrm{air}}$	air mass flow
μ	dynamic viscosity
Δp	pressure drop
p_{H2O}	water vapour pressure
Δh_{ads}	adsorption enthalpy
ρ	density
t	time
T	temperature
$T_{\mathrm{sto}}^{\mathrm{in}}$	temperature at sorption store inlet
$T_{\mathrm{sto}}^{\mathrm{out}}$	temperature at sorption store outlet
u_∞	superficial velocity
$\dot{Q}$	thermal power
x	absolute humidity of air
X_{S}	water vapour load of sorption material