Applied Thermal Engineering 124 (2017) 967–974

Contents lists available at ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Research Paper

Experimental testing of AQSOA FAM Z02/water adsorption system for heat and cold storage

Valeria Palomba [a,b], Salvatore Vasta [a,*], Angelo Freni [c]

[a] Consiglio Nazionale delle Ricerche (CNR), Istituto di Tecnologie Avanzate per l'Energia "Nicola Giordano" (ITAE), Via Salita S. Lucia sopra Contesse n. 5, 98126 Messina, Italy
[b] Dipartimento di Ingegneria – Università degli Studi di Messina, c.da di Dio, 98166 Messina, Italy
[c] Consiglio Nazionale delle Ricerche (CNR), Istituto di Chimica dei Composti OrganoMetallici (ICCOM), Area della Ricerca, Via G. Moruzzi 1, I-56124 Pisa, Italy

HIGHLIGHTS

- The experimental testing of a FAM Z02/water thermochemical storage is presented.
- Daily heat storage, seasonal heat storage and cold storage modes are evaluated.
- Discharge power up to 650 W and storage capacity up to 280 Wh/kg have been measured.
- Practical recommendations for improving the design are given.

ARTICLE INFO

Article history:
Received 28 February 2017
Revised 14 June 2017
Accepted 14 June 2017
Available online 16 June 2017

Keywords:
Adsorption
Thermochemical storage
Zeolite
Testing

ABSTRACT

Thermal energy storage devices are crucial elements, especially in systems employing renewable energy sources. Adsorption-type storages show promising features: high energy density and possibility to be operated for heat and cold release to the user. However, only a few experimental activities on prototypes can be found in literature, especially for low temperature heat storage (<100 °C). In the present work, the design, realization and experimental characterization of a prototype using AQSOA FAM Z02/water as working pair are presented. A specific test set-up, characterised by the possibility of testing different adsorbers configuration, has been developed and an adsorber with 4.3 kg of adsorbent material has been tested under cold storage, daily heat storage and seasonal heat storage operating modes. The prototype is able to store from 620 Wh up to 1100 Wh, with a maximum energy storage density of 280 Wh/kg. The average power during the discharging phase ranges from 200 W to 650 W. Energy efficiencies obtained vary from 1.5 for daily heat storage to 0.3 for cold storage operation.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

The ability to store thermal energy is crucial, especially for exploiting renewable energy sources in heating and cooling systems. A properly designed thermal energy storage system permits to reduce part load operation and to cover the mismatch between energy availability and demand [1]. Generally, thermal energy can be stored in form of sensible heat, latent heat, sorption heat or chemical (thermochemical) heat. R&D is mostly devoted to latent heat storage technology (paraffin, salt hydrates, fatty acids, sugar alcohols) and novel thermochemical concepts relying on chemical or sorption reactions [2,3]. Among the different opportunities, closed-cycle adsorption storage is preferable over other technologies both for daily and long-term energy storage especially for small-scale applications, where a compact equipment is needed [4].

Closed-cycle storage systems basically consists of two separate closed reactors, containing the adsorbent material integrated into a heat exchanger (i.e. the adsorber) and the liquid working fluid (i.e. the condenser/evaporator) [5,6]. Depending on the specific requirement, the evaporator can produce a cooling effect or a heating effect can be recovered from the adsorber. Water is the preferred working fluid, due to the self-evident environmental benefits and its high latent heat of evaporation/condensation. Methanol and ammonia are possible alternatives, especially for those applications where the evaporation temperature goes below 0 °C [7]. Although closed cycle sorption storages systems offer some benefits, there are still some open issues, such as the configuration complexity, poor heat and mass transfer efficiency and low actual heat storage density in real systems [8]. To overcome these barriers, current research on adsorption storage is worldwide in

* Corresponding author.
E-mail address: salvatore.vasta@itae.cnr.it (S. Vasta).

http://dx.doi.org/10.1016/j.applthermaleng.2017.06.085
1359-4311/© 2017 Elsevier Ltd. All rights reserved.

Nomenclature

c_p	Specific heat, kJ/(kg °C)
E	Energy, Wh
m	Mass, kg
$\dot{m}$	Mass flow rate, kg/min
P	Power, W
T	Temperature, °C
t	Time, s
η	Efficiency

Subscripts

ads	Adsorber
cond	Condensation
des	Desorption
ev	Evaporation
in	Inlet
out	Outlet
pc	Phase changer

Acronyms

CS	Cold Storage
DHS	Daily Heat Storage
SHS	Seasonal Heat Storage
PD	Discharge power, W
SE	Stored energy, Wh
SED	Stored energy density, Wh/kg
TCSS	Thermochemical Storage System

progress, but mainly with focus on materials development. Indeed, different sorbents have been proposed in literature, regarding silica gel, standard and modified aluminosilicate type A, X and Y zeolites as well as mesoporous materials impregnated with hygroscopic salts ($CaCl_2$, LiCl, LiBr) with water and methanol as working fluid [5,9–12]. Storage densities ranged from 148 Wh/kg (standard 13X zeolite) to 470 Wh/kg (the novel composite based on Multi-Wall Carbon Nanotubes impregnated with LiCl presented in [13]).

Despite the wide number of studies on possible adsorbents, only a limited research activity is reported on the development of closed-cycle adsorption TCSS. Moreover, most of them cover the application as heat storage at high and medium temperature range (150–250 °C). A literature survey on storage prototypes is presented in [5,14], In [15], Stitou et al. present the experimental characterization of a system for cold storage with daily cooling capacity of 20 kWh and using $BaCl_2$/ammonia as working pair. Storage energy density is 110 Wh/kg and efficiency measured is 30–40%. In [16], Freni et al. present the results of a testing campaign on a system employing the novel composite water sorbent "silica modified by calcium nitrate" (SWS-8L). The measured energy density for cold storage operation is 400 Wh/kg. In [17], Zhao et al. report the development of a 10 kWh storage system employing $SrBr_2$ modified with expanded natural graphite/water as working pair. The measured energy density is 300 Wh/kg at a discharging temperature of 35 °C and 80 °C charging temperature.

In this work, a novel compact prototype of closed adsorption thermochemical storage system (TCSS), employing AQSOA FAM Z02/Water as the working pair, is presented and experimentally tested under different operating conditions. Firstly, the description of the realised system and the testing facilities are introduced. Afterwards, the test protocol is described and the performance features are presented in terms of discharge power, stored energy, energy density and overall efficiency. Influence of the operating conditions on the achievable performance is experimentally studied. Finally, a design analysis is performed, in order to give some practical recommendation useful to improve the design of the systems and reach an optimal compromise between heat power restitution and energy density in the reactor.

2. The realised system

2.1. Prototype of thermochemical storage system

The thermochemical storage tested consists of two vacuum chambers, for the adsorber and the phase changer (working alternatively as condenser and evaporator).

The design of the adsorber has been realised considering the results of the thermodynamic analysis performed in [18], according to which the AQSOA FAM Z02/water working pair has promising characteristics for heat storage at low temperatures. A detailed characterization of the adsorbent material, that has allowed the calculation of heat contributions during heat or cold storage operation, has been experimentally performed at CNR-ITAE Institute in Messina (Italy) and described in [19].

The chamber for the adsorber has been specifically designed to test different configurations, in terms of storage materials and heat exchangers. It is therefore equipped with a removable cover and flexible manifolds. Some flanges allow the connection to the sensors for the monitoring of the most relevant parameters (pressure, temperature) and the other components of the device. The exchanger used for the adsorber is a flat-tube and fins type with exchange area of 1.75 m^2. The exchanger has been filled with 4.3 kg of AQSOA FAM Z02 grains, in the range 1÷2 mm. The material has then been contained by means of a metallic net. The connection between the adsorber and the phase changer is realised through an electrically actuated pneumatic valve. The phase changer consists of a welded chamber, containing 4 commercial fin-and-tube heat exchangers with copper fins and stainless steel tube connected in parallel through an external tubular steel manifold. Each one has an exchange surface of 1.33 m^2. On the chamber, the flanges for the connection to the adsorber and the sensors have been placed.

The test set-up is completed by a hydraulic circuit realised with copper Φ12 mm tubes, thermally insulated by a polyurethane foam with thickness of 1.5 cm. The hydraulic circuits includes 4 3-way valves electrically operated that allow, for each component, the connection to the external hydraulic circuits of the testing rig already present at C E N T R O P R O V E of ITAE in Messina.

Table 1
Main features of the realised thermochemical storage system.

Overall dimensions adsorber chamber	250 × 553 × 774 mm
Adsorber heat exchanger	1 aluminium flat-tube heat exchanger
Exchange area adsorber	1.75 m^2
Adsorbent material	4.3 kg AQSOA FAM-Z02
Overall dimensions of the phase changer chamber	304 × 177 × 298 mm
Phase changer heat exchangers	4 × copper/SS tube-and-fin heat exchangers
Exchange area phase changer	5.32 m^2
Refrigerant	Water
Amount of refrigerant	4 L

Download English Version:

https://daneshyari.com/en/article/4990678

Download Persian Version:

https://daneshyari.com/article/4990678

Daneshyari.com