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Research Paper

Experimental study on adsorption characteristics of a water and silica-gel based thermal energy storage (TES) system

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HIGHLIGHTS

- A lab scale physi-sorption based thermal energy storage system was constructed.
- Water uptake on to silica-gel was measured and compared to an isotherm theory.
- Measured water uptake is only 29.8–56.7% of the theoretical isotherm estimation.

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ABSTRACT

This study is focused on characterizing the adsorption process of a sorption based thermal energy storage (TES) systems. A lab scale closed loop physi-sorption based TES system was constructed and silica-gel (SiO_2) is used as the adsorbent and water as the adsorbate. Experiments are conducted to investigate the impact of the temperature change of the evaporator (T_{eva}) and the mass variation of the water (adsorbate) in the evaporator. Through the test results, three key findings can be identified that mainly affect the adsorption performance. First, a higher evaporator temperature leads to a greater uptake amount (X) because of the larger pressure difference and vapor mass flow rate. Second, the measured adsorption isotherm value in a real system is approximately 29.8–56.7% of the theoretical estimation (D-A isotherm). Third, the geometry of the vapor transmission system determines the ability to transport vapor to the reactor sufficiently and stably.

1. Introduction

Adsorption based thermal energy storage (ATES) is considered to be a promising methodology for long term thermal energy storage because it limits heat loss during the storage period and can yield a much greater energy storage density than other conventional thermal storage technologies [1]. Adsorption is a surface based exothermic reaction between a micro-pore surface material (adsorbent) and gas or liquid reactants (adsorbate). The heat of adsorption is released when the adsorbates react with the adsorbent surface. Thermal energy can be utilized by recovering the reaction heat of adsorption. Desorption is the reverse of the adsorption process. During the desorption process, the adsorbed adsorbate is released from the adsorbent, typically by applying an external heat supply. The adsorbent and adsorbate are separated state during the storage period. By combining these reversible reactions (i.e., adsorption/desorption cycles), a long-term thermal storage technology becomes more feasible due to the small heat loss in the storage state in which adsorbate is released (desorbed) and separated from adsorbent [2].

The basic concept of the ATES process is illustrated in Fig. 1. During the thermal energy charging process (desorption), external heat drives desorbed adsorbate from the adsorbent filled reactor to the condenser where it is stored as condensed liquid. Through this process, the adsorbent-adsorbate working pair is separated and the supplied heat can be stored as a reaction potential. Because the heat loss to the environment due to thermal gradients is minimized, efficient long term thermal energy storage can be realized. On the other hand, during the discharge process (adsorption), the adsorbate that was stored in the liquid phase is evaporated by an ambient heat source and the vapor transfers to the reactor where the dry adsorbent in the reactor adsorbs the transferred adsorbate from the evaporator. The reaction heat is released and can be recovered for external applications. Through this charge/discharge cycle, thermal energy can be recovered for various applications across large gaps in time or spatial distance.

The ideal adsorption based thermal storage cycle, especially a long-term (seasonal) storage cycle, consists of a heating/desorption process, isobaric cooling process, isosteric cooling process and

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