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Laboratory test of a cylindrical heat storage module with water and sodium acetate trihydrate

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Abstract

Cylindrical heat storage modules with internal heat exchangers have been tested in a laboratory. The modules were filled with water and sodium acetate trihydrate with additives. The testing focused on the heat content of the storage material and the heat exchange capacity rate during charge of the module. For the tests with the phase change materials, the focus was furthermore on the stability of supercooling and cycling stability. Testing the module with sodium acetate trihydrate and 6.4% extra water showed that phase separation increased and the heat released after solidification of supercooled phase change material was reduced over 17 test cycles. The heat released after solidification of the supercooled sodium acetate trihydrate with thickening agent and graphite was stable over the test cycles. Stable supercooling was obtained in 7 out of 17 test cycles with the module with sodium acetate trihydrate with extra water and in 6 out of 35 test cycles for the module with thickening agent.

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Keywords: Heat storage; Phase change material; Sodium acetate trihydrate; supercooling.

1. Introduction

Thermal energy storage is needed to match the intermitted supply of solar energy with varying demands. To improve the volumetric storage capacity compared to sensible heat storage, latent heat storage technologies can be used. Sodium acetate trihydrate (SAT) is an incongruently melting salt hydrate with a latent heat of fusion of 264 kJ/kg at a melting temperature of 58 °C [1]. These thermal properties make it a suitable candidate material to

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integrate with solar heating systems, space heating and domestic hot water preparation. Furthermore, SAT has the ability to cool down far below its melting point without solidifying. Letting the SAT remain in this supercooled state in temperature equilibrium with the ambient allows for a partly loss free storage when the latent heat of fusion is stored at ambient temperature. When a heating demand arises, solidification of the supercooled SAT can be initiated and the latent heat discharged. This principle makes compact seasonal heat storage possible [2, 3].

2. Laboratory testing

Two heat storage modules with mixtures based on SAT were tested in the laboratory. The aim was to investigate the functionality of the storage design including utilization of the principle of stable supercooling. The heat charged to and discharged from the modules was measured based on flow rates and temperatures. The heat loss coefficients of the modules were experimentally determined and the heat contents of the stores, the heat exchange capacity rates during charge, the discharge power and temperatures were determined and compared for the different storage mediums.

2.1. Heat storage design

The storage modules were designed as cylinders in stainless steel with a height of 150 cm and a diameter of 30 cm. A layer of EPP insulation covered the cylinders making the total height of the heat storages 160 cm and the diameter 38 cm. The internal heat exchanger consisted of 16 stainless steel pipes located in a circular formation in the length of the cylinder with thin aluminum plates attached as fins to increase the heat transfer area. Manifolds with inlets and outlets were located on the top and bottom of the cylinders. The distance between the aluminum plates were approximately 0.5 - 1 cm.

2.2. Storage materials

The storage was initially tested with water as the storage medium as a reference since it has traditionally been used for short term storage. Sodium acetate trihydrate melts incongruently and its storage potential will be reduced over repeated test cycles due to the phase separation if this is not avoided. Additives such as extra water or thickening agents have been suggested for solving this problem [4, 5]. Adding graphite to the SAT mixture can improve the heat transfer without compromising the stability of the supercooling [6, 7]. The heat storages were tested with three different storage mediums:

- 91 kg water
- 109 kg SAT mixed with 7 kg of extra water
- 111 kg SAT mixed with 580 g Xanthan rubber and 5 kg of fine graphite powder.

Given the respective densities of water and SAT, the modules were filled approximately 90% of the total volume for all storage materials. This was to allow for the expansion and contraction of the storage mediums during heating and cooling.

2.3. Heat storage test setup

The air volume in the top of the cylinder was either connected to an external expansion vessel via a tube to allow for expansion and contraction of the storage mediums inside the module with minimal pressure built-up. Alternatively, an air filter was installed instead of the expansion in the top of the tank to allow for the density changes without pressure built up while reducing the risk of particles to enter the chamber and disturb the stability of the supercooling.

The heat storage modules were connected via a pipe loop with water as the heat transfer fluid to an electric heating element and a central cooling unit. During charge and discharge the flow direction was from bottom to top.