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Combined short and long term heat storage with Sodium Acetat Trihydrate in cylindrical tanks

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Summary

A cylindrical heat storage prototype was designed to utilize Sodium Acetate Trihydrate (SAT) for combined short and long term heat storage. It was manufactured with inexpensive standard components of water stores. It contained 150 liter of SAT composite and 55 l of water. A heat storage test facility was used to investigate if the concept of stable supercooling of SAT can be applied and if thermal power during discharge is sufficient for domestic heat supply. Preliminary results showed that 27 kWh of heat can be stored during heat up to 90°C, which is significantly higher than water heat stores of the same volume. After a heat loss free storage period, 11 kWh (long term storage potential) were discharged during SAT composite solidification. Parallel application of heat storage units should be investigated to overcome heat transfer limitations.

Keywords: Heat storage design; Sodium Acetate Trihydrate; Stable Supercooling; Performance evaluation;

1. Introduction and method

Sodium acetate trihydrate (SAT) has a melting point of 58°C and a latent heat of fusion of 264 kJ/kg (Zalba et al., 2003). It was identified as suitable phase change material (PCM) for heat storage in households for space heating and domestic hot water supply (Zhou et al., 2012). After melting above 78°C (Araki et al., 1995) SAT can cool down to the ambient temperature without solidifying and remain stable in supercooled state. The solidification can be initiated and the heat of fusion released later when heat is in demand. This concept was successfully applied to cylindrical prototype heat storage units (Dannemand et al., 2016). Additives are needed to prevent phase separation when SAT is supercooled below its melting temperature. Kong et al. (2016) investigated different stabilizers and concluded that SAT composites with HD 310, a liquid polymer prototype solution, had high heat of fusion after supercooling periods.

Due to their thermosphysical properties, SAT composites in liquid state enable good heat transfer in vessels by allowing convection. During solidification thermal conductivity decreases and no convective heat transfer is possible. Also, inexpensive heat stores are needed for building application. This has to be addressed by heat storage design. Therefore a cylindrical heat storage prototype based on standard components of water heat stores is presented (scheme in Fig. 1, specification in Tab. 1). It was manufactured by the Danish company NILAN A/S. A steel tank is containing the SAT composition and an internal steel spiral heat exchanger. It is centered in an outer steel tank to realize heat exchange via its outer surface (mantle heat exchanger). An installer friendly modular design was realized by rectangular shaped foam insulation and a metal cabinet with sufficient space for piping (Fig. 1 left). An expansion vessel to compensate density changes of the PCM (~10% of the SAT composite volume) can be placed on top of the cabinet.

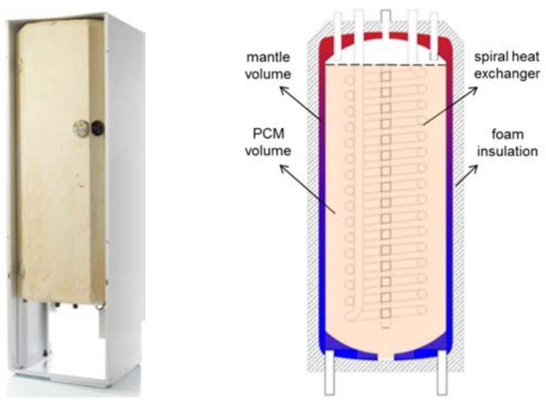

Fig. 1: left: Photography of the cylindrical heat storage; center: schematic drawing (intersection).

PCM filling:	200 kg
Inner tank diameter:	0.45 m
Inner tank height:	1.20 m
Outer tank diameter:	0.50 m
Outer tank height:	1.25 m
Heat transfer area :	2.95 m^2
PCM volume :	<150 l
Mantle volume:	54.6 l
Steel tank mass:	140.8 kg

Tab. 1: Specification of the cylindrical heat storage unit.

A test facility was used to test if the concept of stable supercooling can be applied and if the heat transfer was sufficient for hot water and space heating supply in buildings. A hydraulic circuit with two parallel lines for spiral- and mantle heat exchanger was built. An electric heater for charge and a plate heat exchanger for cooling via a cooling unit were connected. Water was used as heat transfer fluid. Performance evaluation is based on measurements of heat transfer fluid flow rates and inlet and outlet temperatures in both lines.

A SAT composite containing 3% of HD 310 and 2% extra water was filled for initial tests of the storage prototype. Tests on steady state heat losses, and thermal power during charge and discharge with variation of heat transfer fluid flow rates were conducted. Solidification of supercooled SAT composite was initiated by seed crystals which were inserted by an opening to the inner tank.

2. Preliminary results

Heat loss coefficients at steady state (2.2 W/K at 68°C) were similar to water heat stores of similar size and volume-surface area ratio.

Performance evaluation of a tests sequence is presented in Fig. 3. During charge from initially solid PCM state 27 kWh of heat were stored. It was calculated that 20 kWh were needed to heat up and to melt the SAT composition, while 7 kWh correspond to the sensible heat capacities of the steel components and the water of the storage unit. Then it was discharged and the storage cooled down to ambient temperature within 2 hours. The SAT composite remained in stable supercooled state for 15 hours until seed crystal injection took place. As consequence, storage temperature rose to 58°C. Heat of fusion was discharged during PCM solidification with thermal power peaking at ~5 kW. In liquid PCM state the prototype worked as sensible heat storage. Its storage capacity from 20°C to 90°C was 15.5 kWh. After a period without heat losses, which can be extended to weeks or months, 11 kWh of heat was discharged.

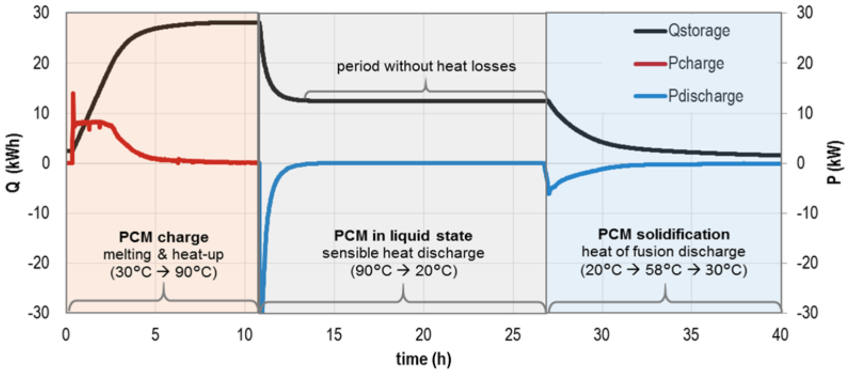

Fig. 3: Development of heat transfer rates and heat content during storage test (7th test sequence).

3. Conclusions and outlook

Utilization of stable supercooling of Sodium Acetate Trihydrate composites for combined short and long term heat storage was successfully demonstrated with a cylindrical heat storage unit. Preliminary results showed short term heat storage potential of 15.5 kWh, which is about 25% lower than for a water store of the same volume. In liquid PCM state domestic heating applications can be supplied with high thermal power. The storage prototype showed 11 kWh of long term storage potential, which can be utilized after long periods without heat losses. During PCM solidification discharge power is limited. Therefore parallel operation of modular heat storage units should be investigated to overcome heat transfer limitations. To utilize heat of fusion close to the melting temperature of SAT composites interrupted discharge via the mantle heat exchanger should be tested. Apart from technical requirements, heat storage units should be inexpensive and durable. Therefore long term stability tests should be conducted.

4. References

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