Thermophysical Properties of Sodium Acetate Trihydrate Composites as Heat Storage Material

Dannemand, Mark; Lazaro, Ana; Delgado, Monica; Peñalosa, Conchita; Peñalosa, Conchita; Trinderup, Camilla Himmelstrup; Johansen, Jakob Berg; Dragsted, Janne; Englmair, Gerald; Kong, Weiqiang; Furbo, Simon

Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

International Renewable Energy Storage Conference **IRES**

IRES 2017 Poster Exhibition
11th International Renewable Energy Storage Conference

Thermophysical Properties of Sodium Acetate Trihydrate Composites as Heat Storage Material

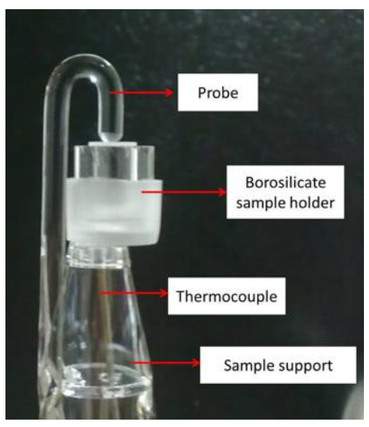
Mark Dannemand[1,2], Ana Lázaro[2], Mónica Delgado[2], Conchita Peñalosa[2], Carsten Gundlach[3], Camilla Trinderup[4], Jakob Berg Johansen[1], Janne Dragsted[1], Gerald Englmair[1], Weiqiang Kong[1], Simon Furbo[1]

[1]DTU Civil Engineering, Technical University of Denmark, Denmark
[3]DTU Physics, Technical University of Denmark, Denmark, [4]DTU Compute, Technical University of Denmark, Denmark
[2]Aragón Institute for Engineering Research (I3A), Thermal Engineering and Energy Systems Group, University of Zaragoza, Spain
markd@byg.dtu.dk

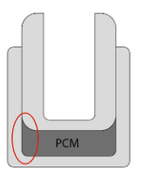
Introduction: Sodium acetate trihydrate (SAT) can be used as a phase change material (PCM) in heat storage applications. The melting point at 58 °C and favorable thermophysical properties makes it a suitable storage material in solar heating systems applications for space heating and domestic hot water preparation. Additives are used to stabilize the PCM, optimize or enhance the material properties and ensure cycling stability.

SAT can be used for long term heat storage by utilizing its ability to supercool stable to ambient temperature or for short term heat storage where the supercooling is avoided. Material investigations were carried out considering the behavior of SAT with and without supercooling.

Density - porosity: The density and thermal expansion of SAT in liquid and solid state was measured. The characteristics of the cavities formed inside of solidified SAT were found by x-ray scanning. The measured density of SAT solidified from a supercooled state was less than the typical literature value. The X-ray scanning confirmed that 15% of the volume of a sample which had solidified from supercooled state was cavities.

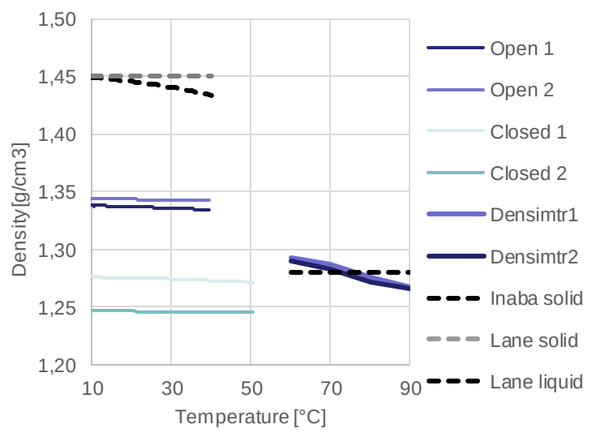


Thermo mechanical analyzer (TMA)

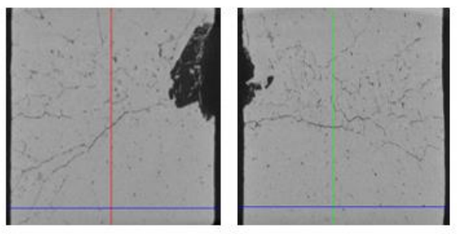
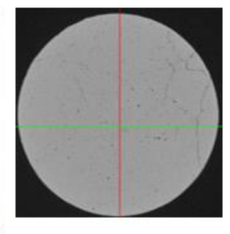


Closed sample holder


Open sample holder

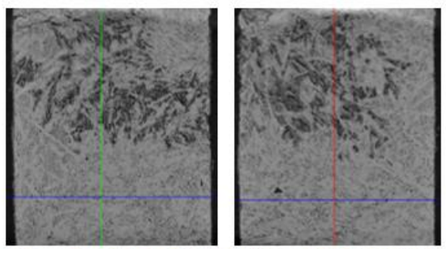


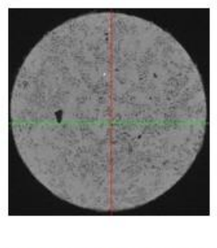
Density measurements vs. literature


X-rayed samples: Ø 10 mm, h = 10 mm

X, Y and Z cut planes and 3D illustration of SAT solidified without supercooling

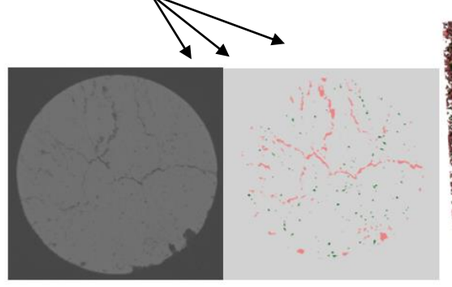


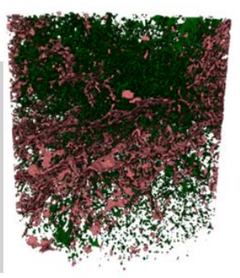


Green = closed cavities

Red = connected cavities

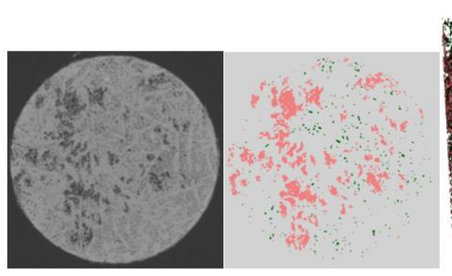
X, Y and Z cut planes and 3D illustration of SAT solidified from supercooled state

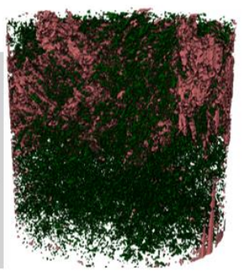



Slice and corresponding segmentation and 3D illustration of SAT solidified without supercooling

Sample	Cavity/ total volume	Enclosed cavity/ total cavity
Solid SAT (non-supercooled)	0.07	0.13
Solid SAT (supercooled)	0.15	0.09

Cavities in SAT samples

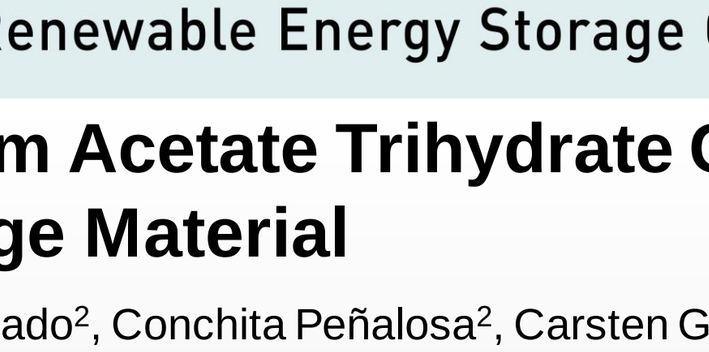



Slice and corresponding segmentation and 3D illustration of SAT solidified from supercooled state

Sample	Density g/cm³
Solid SAT (non-supercooled)	$\rho_{s(non-supercool)} = -7.8 \cdot 10^{-5} \cdot T + 1.3423$ For 10 °C < T < 40 °C
Solid SAT (supercooled)	$\rho_{s(supercool)} = -7.6 \cdot 10^{-5} \cdot T + 1.2622$ For 10 °C < T < 50 °C.
Liquid SAT	$\rho_{l} = -8.63 \cdot 10^{-4} \cdot T + 1.3438$ For 60 °C < T < 90 °C.

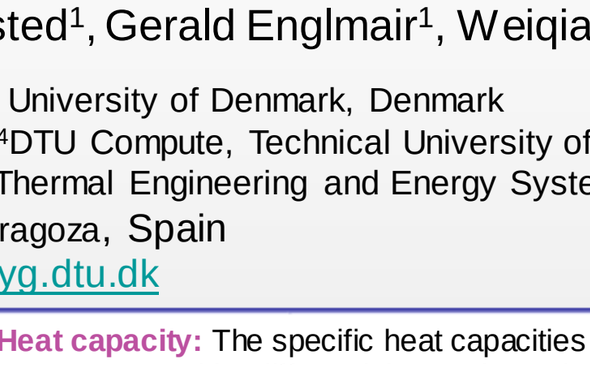
Expressions for solid and liquid density

Heat capacity: The specific heat capacities and latent heat of fusions of SAT composites were measured by differential scanning calorimetry **(DSC)** and the **T-history** method. The measurements showed that the additives had little effect on the specific heat capacities of the SAT composites. SAT composites with CMC or Xanthan rubber was investigated.



Literature values for specific heat of solid and liquid SAT

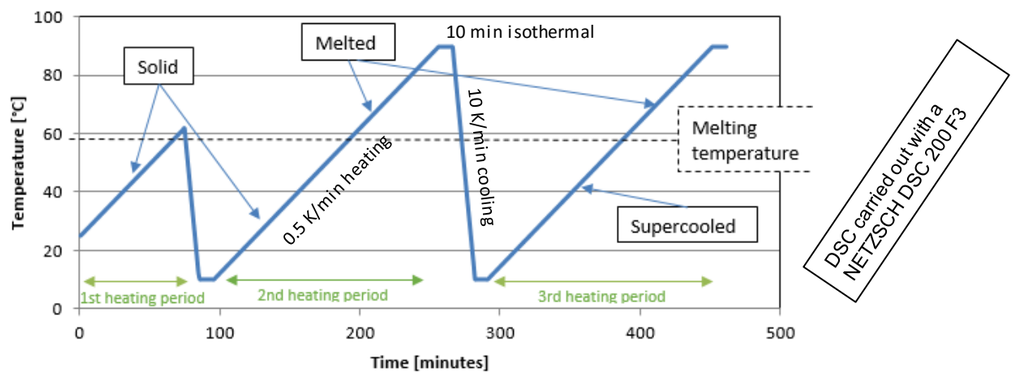

Test tubes with water and SAT composite with needle through septum in screw cap



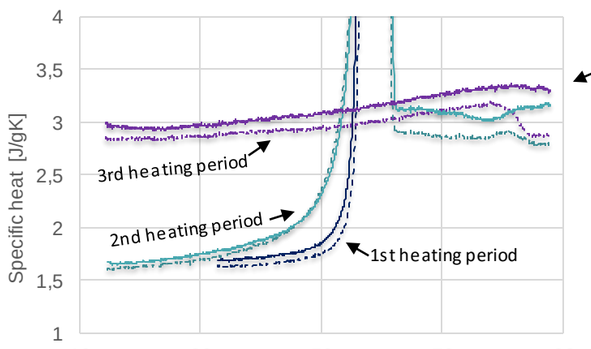
T-history measurements

Sample	Latent heat of fusion [kJ/kg]
SAT (litterature)	265
SAT – CMC	218
SAT – Xanthan	225

Latent heat of fusion values from T-history



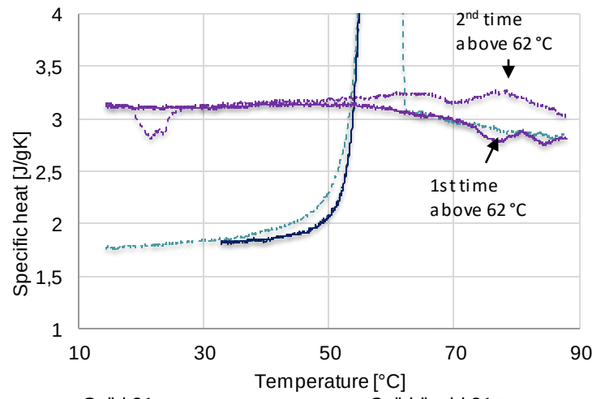
Temperature ramp for DSC.



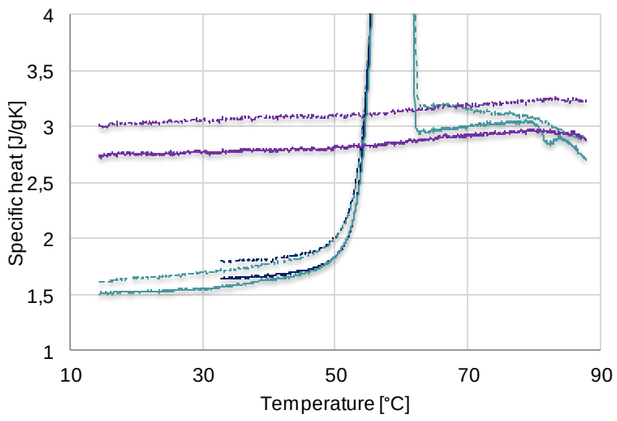
Specific enthalpy for SAT without additives measured with DSC.

Significant difference in measured solid c_p for 1st and 2nd heating period

20 mg SAT – CMC sample did not solidify during 1st cooing period



Specific enthalpy for SAT with 1% CMC measured with DSC.



Specific enthalpy for SAT with 0.5 % Xanthan rubber measured with DSC.

Characteristic drop in measured liquid c_p at around 80 °C

SAT composite with xanthan rubber (X) and xanthan rubber and 10% graphite powder (XC)

References:

M. Dannemand, J.M. Schultz, J.B. Johansen, S. Furbo, Long term thermal energy storage with stable supercooled sodium acetate trihydrate, Appl. Therm. Eng. 91 (2015) 671–678.

N. Araki, M. Futamura, A. Makino, H. Shibata, Measurements of Thermophysical Properties of Sodium Acetate Hydrate, Internaltional J. Thermophys. 16 (1995) 1455–1466.

K.K. Meisingset, F. Grønvold, Thermodynamic properties and phase transitions of salt hydrates between 270 and 400 K III. $CH_3CO_2Na \cdot 3H_2O$, $CH_3CO_2Li \cdot 2H_2O$, and $(CH_3CO_2)_2Mg \cdot 4H_2O$, J. Chem. Thermodyn. 16 (1984) 523–536.

H. Inaba, et al, A study on latent heat storage using s supercooled condition of hydrate (1st report, an estimation of Physical properties of hydrate sodium acetate including a supercooling condition), Japan Soc. Mech. Eng. 553 (1992)

Acknowledgement:

Experimental investigations on density were carried out in the laboratory of the GITSE research group, University of Zaragoza. X-ray scanning was carried out at Department of Physics, Technical University of Denmark. The authors thank the Spanish Ministry of Economy and Competitiveness for the funding of this work within the framework of projects ENE2011-28269-C03-01and ENE2014- 57262-R and the Danish Energy Agency supporting the joint IEA SHC Task 42/ECES Annex 29 program on Compact Thermal Energy Storage, Grant no. 64012-0220.