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Development of Reliable Low-cost Phase Change Thermal Storage Systems For CSP

Investigation of Candidate High Temperature PCMs and Numerical Modelling

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The project aims to develop a reliable and low cost PCM storage system for CSP plants using supercritical-CO_2 as the heat transfer medium. This involves the selection of appropriate PCM candidates in the operating temperature range, testing for their stability and material compatibility, and undertaking computer simulations.

Introduction

Thermal energy storage technology allows improved dispatchability of power output from the CSP plant and increases the plant's annual capacity factor. Latent heat storage using phase change materials (PCMs) potentially allows a large amount of energy to be stored in a relatively small volume by using the material's heat of fusion, resulting in a smaller and less costly storage system compared to sensible thermal storage systems [1]. A significant amount of the energy is also stored and released at a constant temperature.

The overall objective is to develop a high performing thermal storage system using PCM as the storage medium, costing less than \$25/kWh_{th}.

Computer Simulation

- The current numerical models are written in FORTRAN 6.5. It will now be interpreted into Modelica and integrated into the system modelling.
- A cascaded latent heat storage system was designed to enable a discharge duration of 6 hours for a 50 MWh solar tower power plant using s-CO_2 as the heat transfer fluid [2].

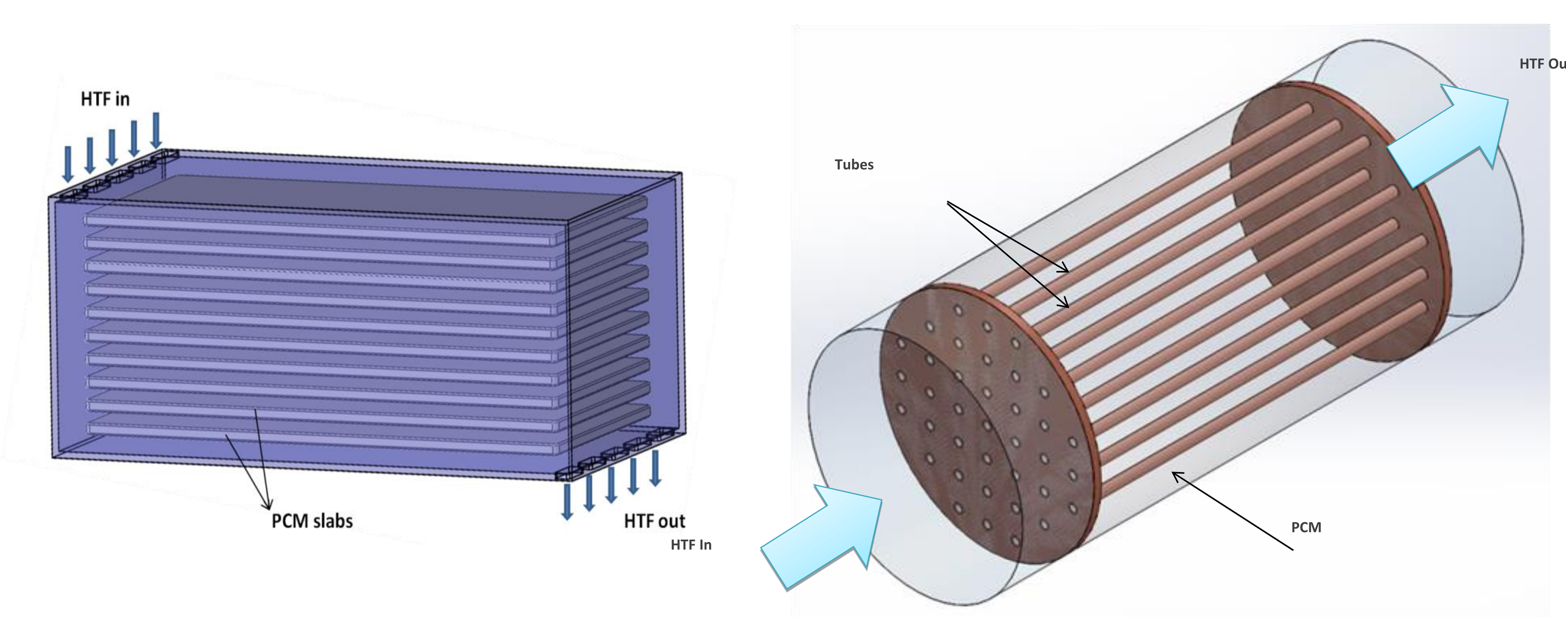

Figure 1: Two configurations of PCM thermal storage systems: flat plate (left) and shell-and-tube (right).

PCM Characterisation, Stability and Corrosion Tests

- Several PCM candidates were characterised. This temperature range was selected to allow for a cascaded PCM storage system to be developed for current and future solar tower power plants.
- The thermal stability of the PCM was evaluated based on the cycling test.
- Good chemical and thermal stability are necessary to ensure a reasonable life span of the storage system.

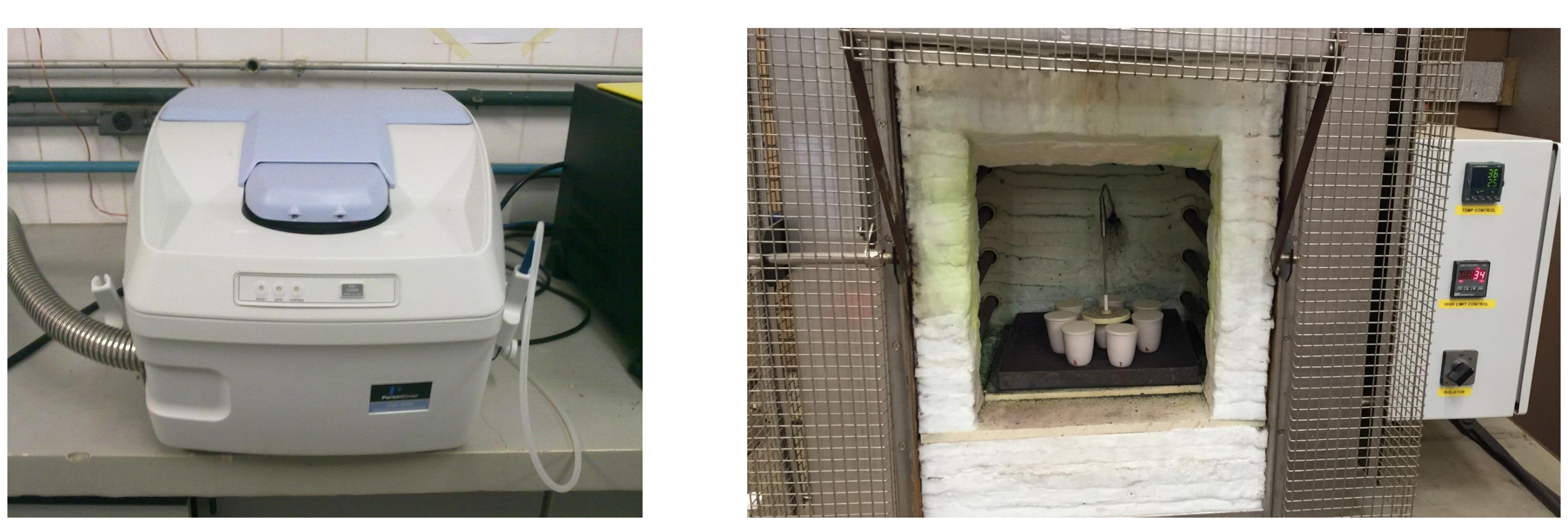

Figure 2: Pictures of DSC (left) and high temperature furnace (right) at UniSA.

Results

Computer Simulation

- Cascaded PCM arrangement is required to effectively extract both sensible and latent energy stored within the PCM [2].
- Increasing the number of PCM systems in series increases the effectiveness of the extracted sensible energy storage [2].

PCM Characterisation

Table 1: Thermo-physical properties of several PCM candidates.

Eutectic Composition (wt.%)	Melting point (°C)	Latent heat of fusion (J/g)	Sub-cooling (°C)	Specific heat, solid (J/g·K)	Specific heat, liquid (J/g·K)
$32Li_2CO_3$–$35K_2CO_3$–$33Na_2CO_3$	396.7	278.9	22.7	1.42	1.68
$28.5Li_2CO_3$–$71.5K_2CO_3$	479.9	234.3	39.5	1.29	1.66
$35Li_2CO_3$–$65K_2CO_3$	503.7	295.2	58.6	1.43	1.73
$52MgCl_2$–48NaCl	439.1	204.2	8.4	1.07	-
$64MgCl_2$–36KCl	459.1	210.2	8.3	0.73	-
$60MCO_3$–40MCl	637	283.3	-	-	-
Li_2SO_4 (solid-solid)	575	243	-	-	-

Corrosion Testing

- PCM 400 with SS304 (a passivation layer formed between the metal and the salt, no corrosion was observed).

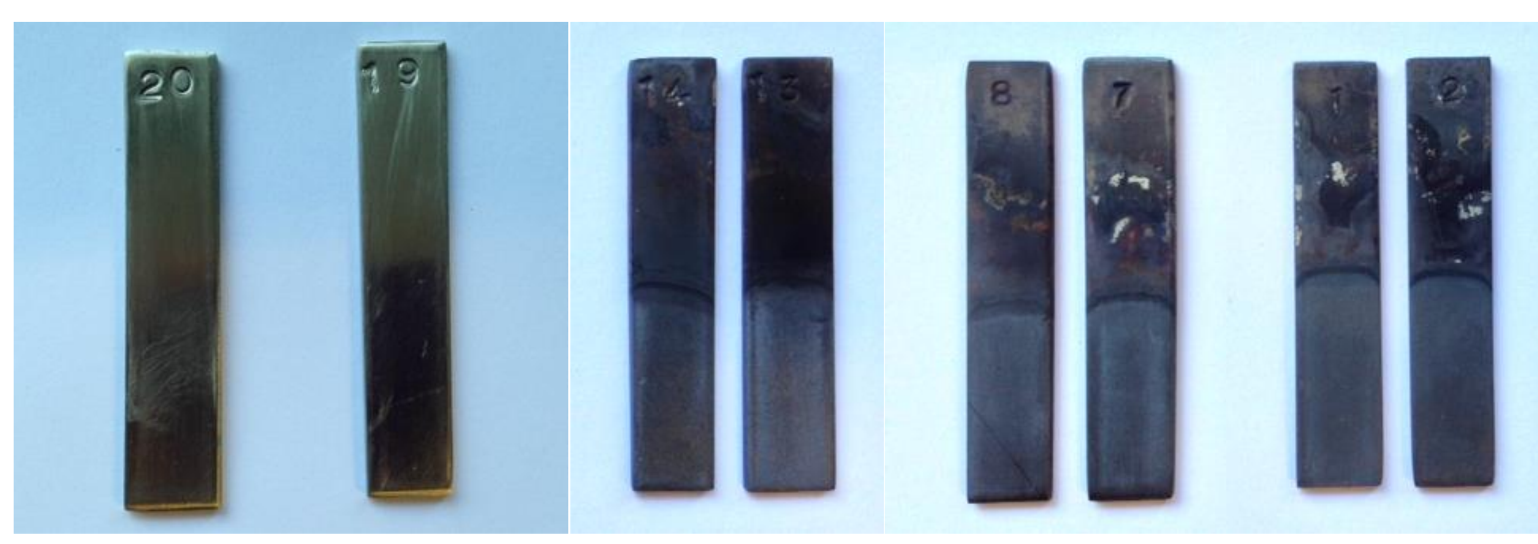

Figure 3: Pictures of SS304 samples after immersion in molten PCM 400.

- PCM 630 with SS316 (corrosion has been observed).

Figure 4: Pictures of SS316 samples after cycling test.

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[1] Gil *et al.*, 2010. Renewable and Sustainable Energy Reviews, Vol. 14, pp.31-55.
[2] Liu *et al.*, 2015. Energy Procedia, Vol. 69, pp.913-924.

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