High Temperature Combined Sensible-Latent Thermal Energy Storage

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1. Introduction

IN-POWER H2020 project aims at developing and integrating new innovative material solutions into CSP technology to increase the efficiency while simultaneously decreasing the energy production cost. These advanced material solutions consist of self-healing and anti-soiling coated mirrors, optimized mirror support structure, high-temperature absorber coating, and high-temperature Thermal Energy Storage (TES) materials and designs leading to the reduction of storage system size. Proposed innovative TES materials could operate with high efficiency thermodynamic cycles working at 600°C. To do this, for CSP plants with gases or molten salts as HTF, high thermal capacity molten salts will be used in thermocline tanks with encapsulated PCM top layer to limit the temperature degradation during discharge and thus increase the utilization rate of the storage system. AlSi12 (melting temperature: 575°C) has been identified to have superior properties for a PCM: high specific energy density and volumetric heat of fusion, good thermal conductivity, low cost, and low environmental impact [1]. As compatibility between PCM and containers is a critical point, innovative anti-corrosive layers under development at CEA will be tested to avoid creep corrosion. IN-POWER TES design has been modeled and its thermal performances are compared to thermocline storage without PCM.

2. Model description and validation

A one dimensional dynamic model of thermocline TES system was developed, taking into account the temperature gradient in axial direction (along the height of the tank), measured thermo-physical properties for the storage media, and realistic heat losses to the environment. To do this, existing continuum thermodynamics models of dual-media thermocline systems [2] were extended with the additional use of a top PCM layer. This model has been adapted in Modelica language within the Dymola platform.

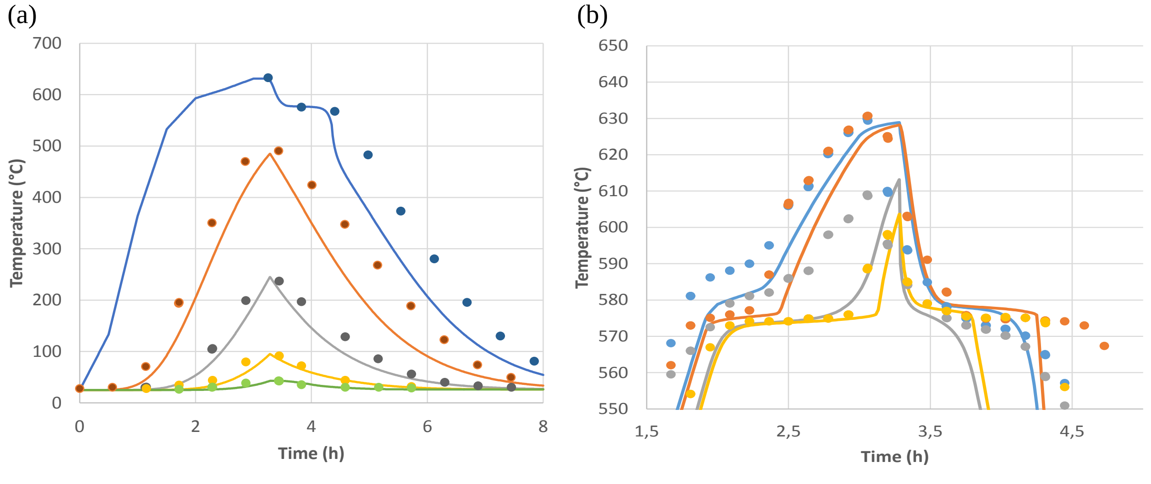

Fig. 1: Experimentally measured (markers, from [3]) and simulated (curves, this work) temperatures during charge and discharge: packed bed and inlet (top) temperatures in the sensible section (a); PCM and air temperatures in the latent section (b)

To our knowledge, there is no existing experimental facility of molten salt thermocline storage with PCM top layer. To validate our model we chose to compare its results with experimental data from a combined sensible latent packed bed tank of rocks and AlSi with air as HTF [3]. A quite good agreement of the simulated results can be observed in Figure 1 for both latent and sensible section. Radiative heat transfers are neglected, which could partially explained the deviations from experimental results.

3. Storage design

Some recent studies have shown the interest of adding a top layer of PCM in a packed bed [4] or in mid-temperature molten salt thermocline [5] TES. A molten salt (Solar Salt) single media thermocline tank was modeled, with different amounts of PCM (AlSi) for the same total tank volume. In Figure 2, simulated outlet temperatures profile in discharge are presented for TES subjected to the same charge and discharge conditions (inlet temperatures and flow rates, final charging outlet temperature). In such conditions a 15% (in volume) PCM layer can extend the discharge time by up to 12% for the same TES volume.

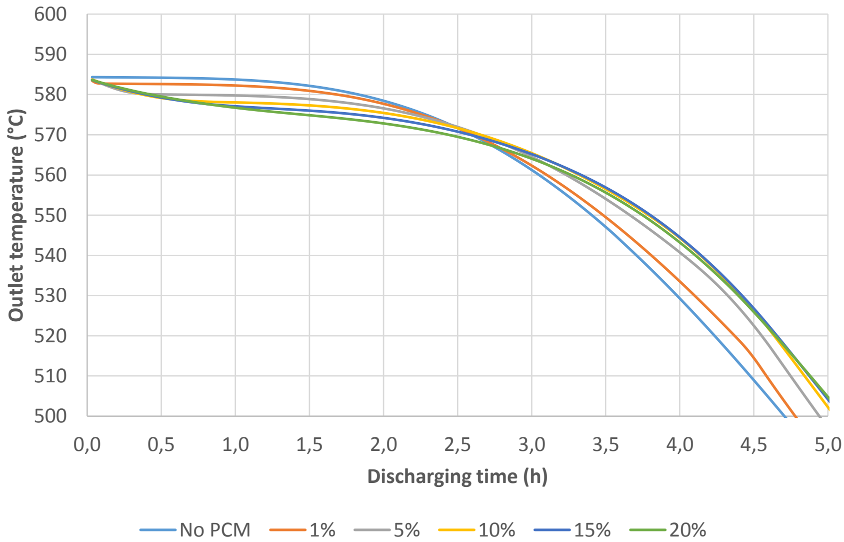

Fig. 2: TES outlet temperature during discharge for different amounts of PCM, for a 100 MWh_{th} storage tank

4. Outlook

This simulation model of the PCM storage will be further validated with tests results from IN-POWER partners. It will be used to design and size high temperature thermocline storage for commercial scale CSP plants. Parametric studies will be performed to optimize tank geometry and operating strategies. Through this work, we will develop a cost-performance model to determine the unit cost of storage capacity (€/kWh) for a given operating temperature range and storage materials combination.

References

[1] S. Khare, M. Dell'Amico, C. Knight, S. McGarry, Solar Energy Materials and Solar Cells107 (2012) 20–27.

[2] T. Esence, A. Bruch, J.F. Fourmigué, B. Stutz, Proceedings of the 23rd SolarPACES Symposium, Santiago de Chile (2017).

[3] G. Zanganeh, R. Khanna, C. Walser, A. Pedretti, A. Haselbacher, and A. Steinfeld, Sol. Energy, 114, (2015) 77–90.

[4] A.B. Hernández, I. Ortega-Fernández, I. Uriz, A. Ortuondo, I. Loroño, J. Rodriguez-Aseguinolaza, Proceedings of the 23rd SolarPACES Symposium, Santiago de Chile (2017).

[5] P.A. Galione, C.D. Pérez-Segarra, I. Rodriguez, S. Torras, J. Rigola, Solar Energy 119 (2015) 134–150.