ASIA-PACIFIC
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Modelling a Hybrid Sensible-Latent Heat Thermal Energy Storage System for CSP Plants

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Concentrated Solar Power Plants (CSP) are capable of generating dispatchable electricity from solar energy at large scale by the integration of thermal energy storage systems. Sensible heat thermal energy storage (SHTES) and latent heat thermal energy storage (LHTES) systems are two viable options. While the sensible heat storage system is commercially available, the latter is at the research and development stage. Using the heat capacity of a candidate storage material provides storage of sensible heat whereas a phase change material (PCM) is capable to store latent heat at constant temperature. Research in this area has shown higher efficiencies are achievable using a combination of storage materials, e.g., multiple PCMs and/or hybrid systems of sensible and latent heat storage materials.

Higher efficiencies in a CSP plant requires higher operating temperature and/or pressure which in turn requires a high temperature storage system. New sensible heat storage as well as PCMs within innovative combinations are required to provide high thermal performance at high temperatures. This study aims to explore a new combination of storage materials which results in an overall higher efficiency and thermal performance.

Numerical modelling provides a virtual platform to explore the thermal performance of different combinations of high temperature sensible and latent heat systems. In this work Fluent [1], a commercially available code, and an in-house one-dimensional code namely the ε-NTU method [2] were used.

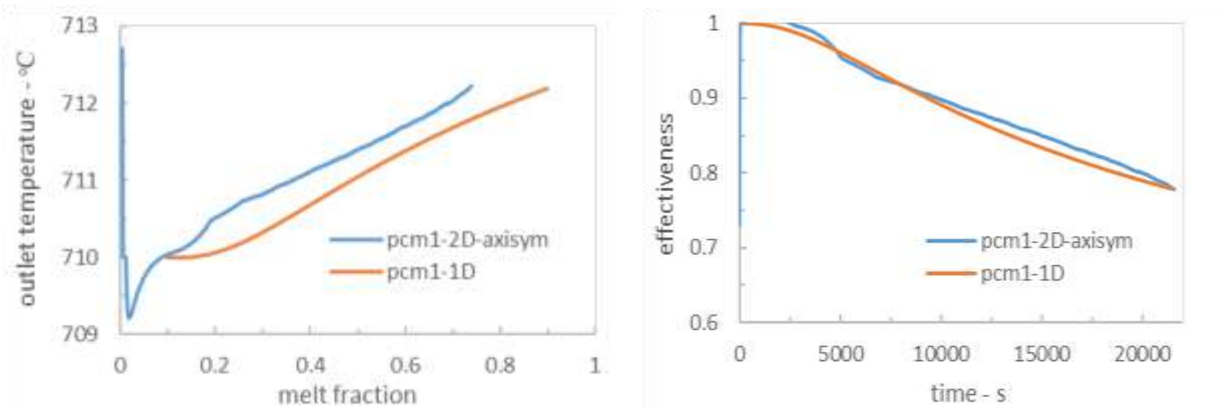
Shell and tube type thermal energy storage systems have been proven to be a promising system for LHTES, whereby the heat transfer fluid (HTF) flows through the tubes and the shell confines the storage material [3, 4]. Previous study by the authors [5] has shown a horizontal parallel flow configuration is a feasible option for a LHTES. In this study, a module of such a shell and tube system was used in the numerical modelling of the charging and discharging processes. The module comprises of three sections; PCM1, graphite, and PCM2 as it is shown in Figure1. Thermophysical properties of the thermal storage media are shown in Table 1. Sodium (Na) was selected as the HTF due to its high thermal conductivity and low viscosity. The inlet temperature of the HTF was 720˚C.

Table I. Thermophysical properties of the storage media

	Melting Temperature [˚C]	Density Kg/m^3	specific heat capacity, J/kg K	Thermal conductivity W/m K	latent heat kJ/kg
PCM1	710	1880	1600	0.5	163
Graphite	----	1808	1600	50	----
PCM2	560	1800	1600	0.5	163

Figure 1. A module of the hybrid horizontal parallel flow shell and tube system

The ε-NTU method provides a means for one-dimensional modelling of charging and discharging of a PCM. In this work, Fluent was used for two-dimensional axisymmetric modelling of the charging and discharging of PCM1 to compare and validate the results from the ε-NTU method for the case of high temperature PCMs. This comparison showed good agreement. Therefore the ε-NTU method was used for the modelling of PCMs to explore different lengths and heat recovery of PCMs as it takes much less computational time. For the charging and discharging modelling of the sensible heat storage/release through graphite, Fluent was used.



(a) (b)

Figure 2. Results of 1D (ε-NTU) and 2D (Fluent) modelling of melting process of PCM1;
(a) outlet temperature of HTF vs melt fraction, (b) effectiveness vs melting time

An exergy analysis provides a means to assess the useful heat recovery from the thermal storage system to the power block in a CSP plant. Using constraints of 6/10 hours for charging/discharging time, the results of the heat transfer modelling were used for an exergy analysis. The results of this study can be used for the design and optimisation of a hybrid combination of SHTES-LHTES.

References

[1] ANSYS Fluent Users Guide, Release 15.0. ANSYS; 2015.

[2] Belusko M, Halawa E, Bruno F. Characterising PCM thermal storage systems using the effectiveness-NTU approach. International Journal of Heat and Mass Transfer. 2012;55:3359-65.

[3] Belusko M, Tay NHS, Liu M, Bruno F. Effective tube-in-tank PCM thermal storage for CSP applications, Part 1: Impact of tube configuration on discharging effectiveness. Solar Energy. 2015.

[4] Belusko M, Tay NHS, Liu M, Bruno F. Effective tube-in-tank PCM thermal storage for CSP applications, Part 2: Parametric assessment and impact of latent fraction. Solar Energy. 2015.

[5] Riahi S, Saman WY, Bruno F, Belusko M, Tay NHS. Comparative study of melting and solidification processes in different configurations of shell and tube high temperature latent heat storage system. Solar Energy. 2017;150:363-74.