Performance simulation of a latent heat storage device using the Particle Finite Element Method (PFEM)

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1 Introduction

Thermal Energy Storage (TES) is a promising approach to climate change mitigation. For instance, it allows increasing the performance of renewable energies by storing the excess energy in the period of high generation, and reusing it in periods of low energy production. Among the different types of TES devices, the ones using Phase Change Materials (PCM) stand out, because thermal energy is stored as latent heat of fusion, allowing to store more energy than TES storing sensible heat.

A TES device based on a Phase Change Material (PCM) operates in 3 stages. The first is the charging stage, in which heat from an external source is transported to the TES unit by a fluid, as shown in Figure 1 (red line). By conduction, heat is transported from the pipe to the fins and to the PCM, which is initially in a solid state (light blue color in Figure 1). As the temperature of the PCM increases, it will eventually undergo phase change to liquid. The difference in temperature and density in the molten PCM will produce convective flow, which will distribute the heat within the TES. Once the TES device is charged, the retention stage begins, in which heat losses must be as low as possible. The third stage of the cycle consists of recovering the thermal energy, i.e. transferring the heat from the PCM to the source fluid.

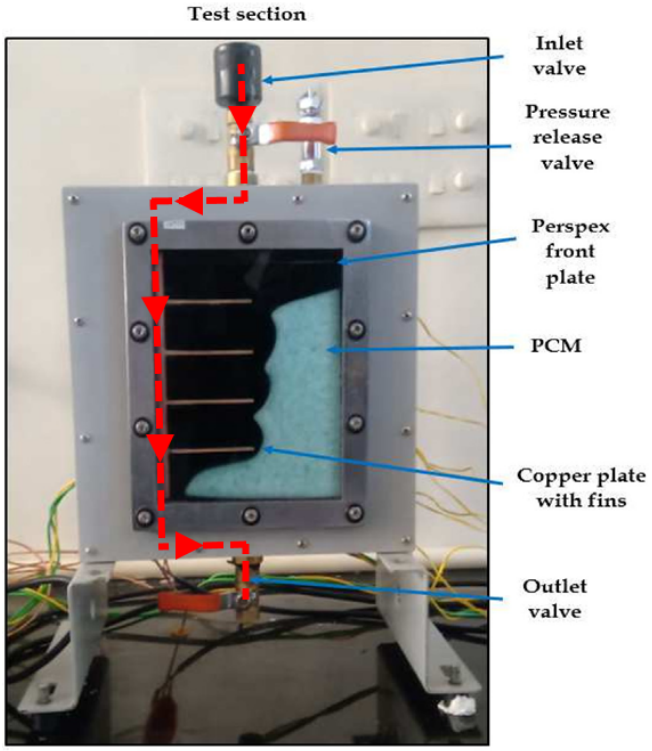
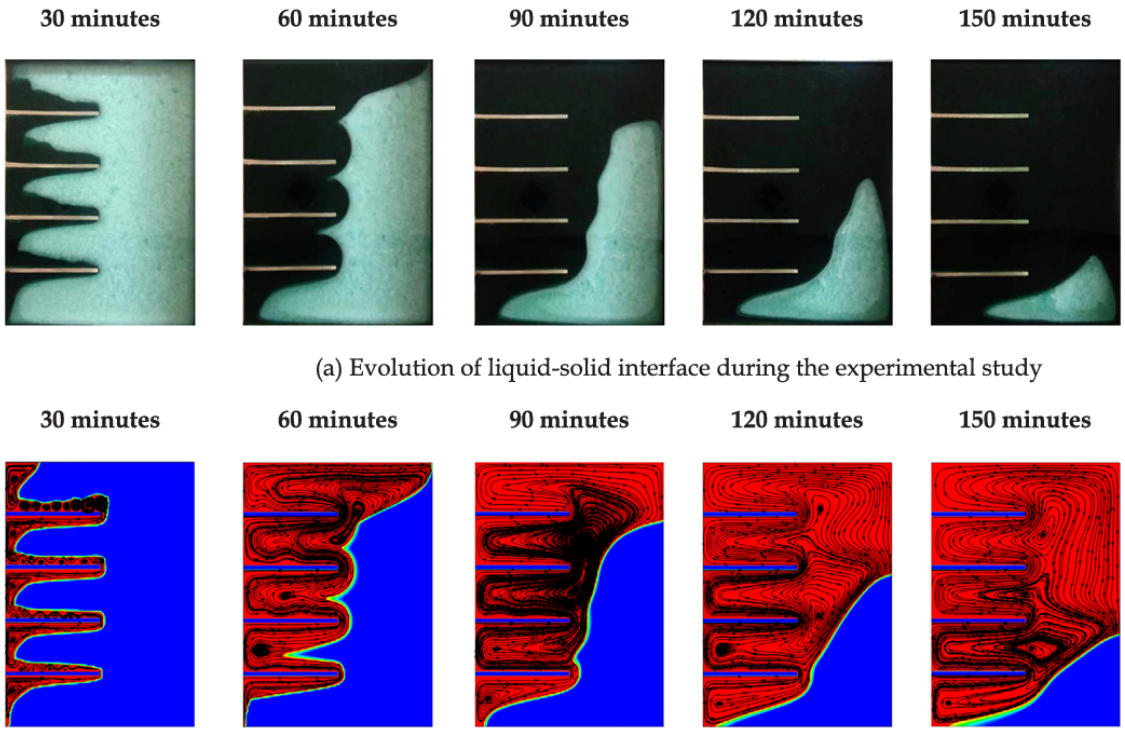


Figure 1: TES device storing latent heat of fusion. The image corresponds to the experimental test of Joshi and Rathod (2020).



(a) Evolution of liquid-solid interface during the experimental study

Figure 2: Results from experiment (top) and simulation (bottom) achieved by Joshi and Rathod (2020).

The performance of TES depends on the amount of energy it stores, the time required to store that energy and to extract it, and the losses in the retention stage. The literature shows that performance of TES devices is highly dependent on their design, i.e., the size and position of the pipes carrying the source fluid, the type of material used for the phase change, and the fins arrangement used to transport the heat from the source to the phase change material. Therefore, the design of TES devices based on PCM must be supported by simulation tools that allow predicting their performance.

2 Objective

The objective of this work is to simulate the performance of a TES device based on PCM using the Particle Finite Element Method (PFEM). As a benchmark test case, this work will consider the experimental and numerical setting of Joshi and Rathod (2020), who report comparisons between simulations and experimental results, as shown in Figure 2.

References

Joshi, Varun, and Manish K Rathod. 2020. "Experimental and numerical assessments of thermal transport in fins and metal foam infused latent heat thermal energy storage systems: A comparative evaluation." *Applied Thermal Engineering* 178: 115518.