Application of Solar Thermal Energy to Processes

D4.2 Modelling and simulation of the charging and discharging cycles of the TES

ASTEP project creates an innovative Solar Heat to Industrial Processes (SHIP) concept. The proposed solution is based on modular and flexible integration of two innovative designs: one for the solar collector, namely the SunDial; and the other for the Thermal Energy Storage (TES); both integrated via a control system allowing flexible operation and continuous service.

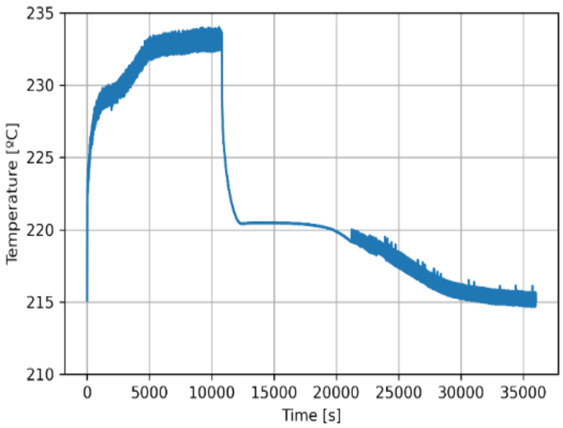

Fig. 1: Temperature evolution for the charging cycle.

Therefore, the TES needs to be analyzed for the expected operational conditions that the systems will operate in both Industrial Sites. The first one belongs to ArcelorMittal Tubular Products (AMTP), with a heating demand above 220 °C for preheating tubes at factory located at a latitude of 47.1 N (Iasi, Romania). The second site is the dairy company Mandrekas (MAN), located at a latitude of 37.93 N (Corinth, Greece) with a heating demand for steam at 175 °C and a cooling demand at 5 °C.

A previous stage to the analysis of the TES is the validation of the CFD model. The validation aims at ensuring that the developed CFD model correctly replicates the phase change of the PCM, since it is in this material where the energy collected from the sun is stored for later applications.

The validated CFD model has been used to simulate the final TES design under a set of charging and discharging cycles for different operating conditions. The PCM transition from solid to liquid phase during charging and from liquid to solid phase during discharge has been studied, together with the temperature distribution, and the buoyancy effects inside the TES when the PCM is melted. We show the main conclusions of the analyses for one operational condition, see Fig. 1 for temperature evolution of the charging cycle.

- **PCM Charging:** The Heat Source wall was maintained 5 ºC above the PCM average temperature, from 190 to 240 ºC. The whole system was set at an initial temperature of 190 ºC. Under such conditions, the system took 93 minutes to reach objective temperature (240 ºC). PCM reached the melting point at about minute 30. At this moment, the temperature rise was slower during phase change for another 30 minutes, and it was then increased quickly towards 240 ºC. It has been observed that the liquid movement due to the buoyancy effects produces a relatively smooth gradient of temperature along the PCM.
- **PCM Discharging:** The heating wall was varied in this case from 235 ºC to 180 ºC, being 5 ºC below the PCM average temperature. The system was defined at an initial temperature of 235 ºC. The solidification process occurred homogeneously regardless the height of interest compared to the melting process, growing from the walls towards the centre, and with no differences along the length. The effects of buoyancy disappear.

We show the charging cycle using the temperature variation and the liquid fraction evolution, the results are shown at 3 planes (symmetry X-plane, symmetry z-plane, and midplane (parallel to the hot plate surface at insert's half height). The results are shown at Fig. 2.

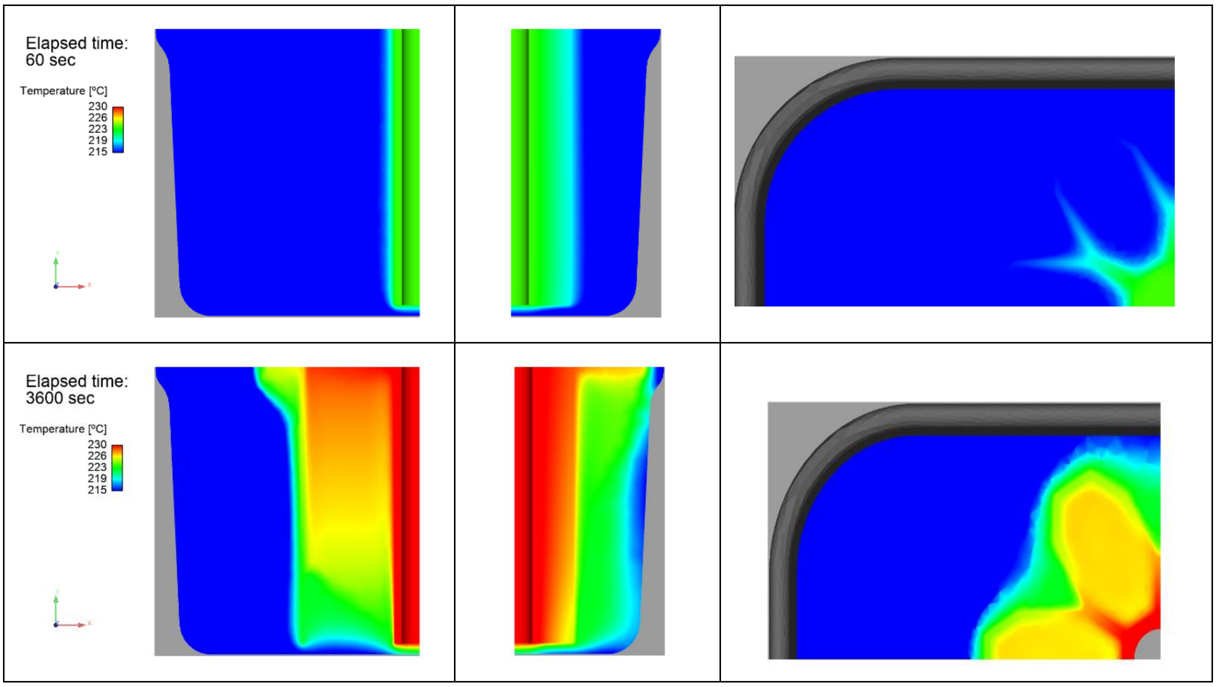

Fig. 2 Validation case – Temperature

The previous results from Fig. 2 show the importance of the convective forces as the upper part of the TES reaches a higher temperature earlier than the lower part. Similarly, the heat is transferred outwards from the heated center towards the outside of the experimental test rig.

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