PERFORMANCE CHARACTERIZATION OF A TECHNOLOGY FOR THERMAL ENERGY STORAGES

Stefan Krimmel[a,b], Romeo Ralon[a], Anastasia Stamatiou[b], Jörg Worlitschek[b], Heimo Walter[a]

[a]E302 - Institute for Energy Systems and Thermodynamic
[b]University of Applied Sciences Lucerne - T&A, CC TES, Switzerland

INTRODUCTION

In the case of latent thermal storage units with indirect heat transfer technologies, the output is still sufficient for the design process even with a high degree of solidification. Due to an insulating layer of solidified storage material, a liquid-solid phase change material (PCM), the efficiency decreases over the time drastically. To reduce this effect, the surface of the heat exchanger is enlarged by finned tubes or by tube bundles. The fins and the high number of tubes will increase the costs and reduce the specific power and capacity of the storage.

The heat transfer concept of direct contact in theory promises to reach high specific power and capacity without the named disadvantages. By this technology, a heat transfer fluid (HTF) that is not soluble with the PCM flows directly through the liquid PCM as a swarm of droplets, see Figure **1** (i). Even the complete PCM is solidified a flow of the HTF is due to channels in the solidified matrix still possible.

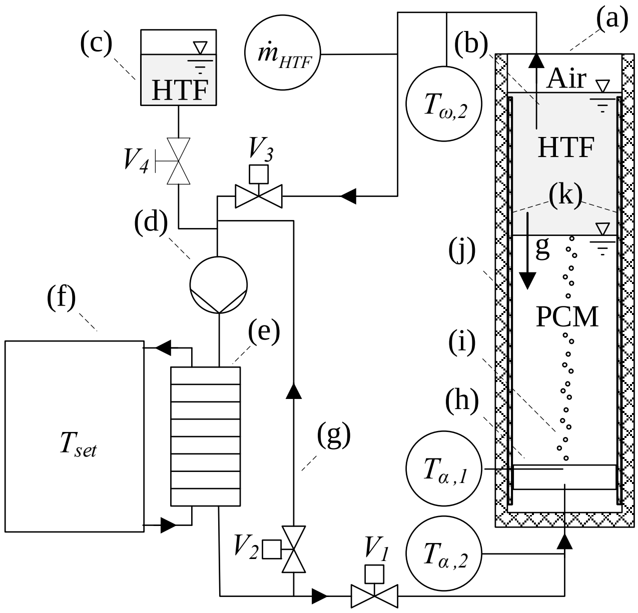

Figure 1: Flow chart of experimental set-up.

(a) Storage tank; (b) outlet extraction; (c) expansion tank; (d) pump; (e) plate heat exchanger;(f) thermostat unit; (g) by-pass; (h) nozzle plate; (i) droplet flow, ascending against the gravity; (j) insolation; (k) plate LED strips.

The presented research work investigates the dominant heat transport mechanisms in a latent direct contact storage. The aim of this research is the mathematical description of the thermal performance curve via the degree of solidification as well as the identification of design guidelines in order to adapt the performance curve to the process requirements during design. Experimental investigations are carried out on a 12 l storage tank in the laboratory and numerical investigations in 2- and 3-dimensional space.

The results of a series of preliminary tests with one nozzle and the material combination H2O - thermal oil are presented. The performance curves during solidifying and melting are discussed on the basis of dimensionless key figures and image recordings of phase change process with regard to the identification of the dominant heat transport process. In the field of numerical investigations, the models and initial results of a sensitivity analysis are presented and discussed.

EXPERIMENT

The test rig shown in Figure 1 is used for the experimental investigation. The storage tank is optically accessible through an insulating glass pane. This enables the solidification and melting processes to be observed. From the observations, explanatory approaches for the course of heat transfer performance can be derived.

Seven preliminary tests will be carried out, whereby the nozzle Reynolds number ranges from 600 to 6000 and the thermal power from 250 to 2500 W. Orifices with a diameter of 2 and 5 mm are used as nozzle.

EXPERIMENTAL RESULTS

The courses of the measured temperatures and calculated powers are evaluated dimensionless. The evaluation shows that there is obviously a critical charge level of the storage as a function of the nozzle Reynolds number. Up to this critical charge level, the power decreases linearly. From the critical charge level onwards, the transmitted power decreases drastically. The optical documentation allows to identify the critical charge state as the state in which the dominant heat transfer mechanism changes from liquid-liquid to liquid-solid. This information is important for the definition of the suitability for further nozzle arrangements.

NUMERICAL MODEL

The numerical investigations are performed in ANSYS Fluent. The Volume of Fluid approach is chosen for the illustration of the multiphase flow. The aim of the simulation on one hand is to be able to map the influences of fluidic installations and on the other hand to map parameters of the material pairings on the system behaviour. In 2-dimensional space, the influences of internals on the multiphase flow are investigated. In 3-dimensional space, the influence of the material pairing and the temperature stroke on the solidification and melting process is mapped.

NUMERICAL RESULTS

The simulations of multi-phase flows require very fine network resolutions and short time steps, as a result of which high computing power is required. Even if the calculations are carried out on the Vienna Scientific Cluster (VSC-3), the dimensions of the laboratory storage device are too large as a reference for the simulation. The results of the solidification of a single droplet are shown and the sensitivity to network resolution and time step is discussed.

CONCLUSION

The evaluation methodology was confirmed as suitable in the preliminary test series. To optimize the documentation, an optically fully accessible and higher storage device is built. The influence of the number of nozzles and the fluid-dynamic cross-sectional load on the position of the critical charge level is to be determined at this accumulator.

The modelling for the simulations has been completed and the first parameter studies can be carried out. These can only be evaluated qualitatively and not quantitatively until the results have been validated. For validation, a suitable compromise between the size of the domain and that of the storage tank must be found.