INNOSTORAGE – USE OF INNOVATIVE THERMAL ENERGY STORAGE FOR MARKED ENERGY SAVINGS AND SIGNIFICANT LOWERING CO_2 EMISSIONS

Beneficiaries:

Partners:

D7.2 - Report on Staff Exchanges

	Name and Institution	Date
Prepared by:	Gennady Ziskind Ben-Gurion University	29.9.2014
Checked by:	-	-
Approved by:	Prof. Dr. Luisa F. Cabeza Universitat de Lleida	29.09.2014

Contents

1 Objectives

The main objective of the secondment is to look into a possible synergy between the two teams whose expertise is mutually complementary. The research team of the Heat Transfer Laboratory, Ben-Gurion University, has made much progress in modeling and experimentation of solid-liquid phase change processes, with special attention to the geometries commonly encountered in or suggested for the latent-heat thermal energy storage (LHTES) systems, which use phase-change materials (PCMs). The research team of Prof. Jay Khodadadi, Auburn University, has made original contributions to experimentation and modeling of nano-enhanced PCMs. The visit is supposed to exchange knowledge and start cooperation in which both teams will contribute from their unique experience and benefit from the expertise of one another. The project is related to Tasks 3.1, 3.2, 4.1 and 4.2. A secondary goal is to discuss about further collaborations and share different ideas for research.

2 Introduction

Active research is performed in modeling and experimentation of solid-liquid phase change processes, with special attention to the geometries commonly encountered in or suggested for the latent-heat thermal energy storage (LHTES) systems which use phase-change materials (PCM). Due to the geometry, the processes in these systems are multi-dimensional and complicated, and include such phenomena as convection in the liquid phase, sinking of solid in the liquid, and volume change due to phase change. Thus, their reliable modeling requires significant efforts. Also, experimentation in this field is quite difficult and could lead to results rather different from those characteristic of thermal-storage applications.

3 Description of work

Specifically, we explore concentric storage units where the charging/discharging process is driven by a hot/cold heat transfer fluid (HTF), flowing inside the tube from which heat is conducted to the fins that are in contact with the bulk of the PCM inside a cylindrical shell, causing the PCM to melt/solidify. Unlike previous works published in the literature, the envelope of the unit is exposed to a heated environment and close-contact melting (CCM) takes place on the upper surfaces of the fins. It is demonstrated that CCM affects noticeably the melting rate and shortens the melting time considerably, meaning that the role of fins is much more important than to just commonly serve as extended surfaces for heat transfer enhancement. Original numerical models are developed based on a combination of an enthalpy method with CCM modeling. Accordingly, they account for various processes that comprise melting.

4 Materials and Methodology

An experimental system, dedicated to this project, is shown in Figure 1. The set-up includes a storage unit connected to two thermostatic baths with precise temperature control. Depending on the process required – heat charge or discharge – hot or cold heat transfer fluid is supplied to the unit, allowing for cycle-type experiments that reflect the reality.

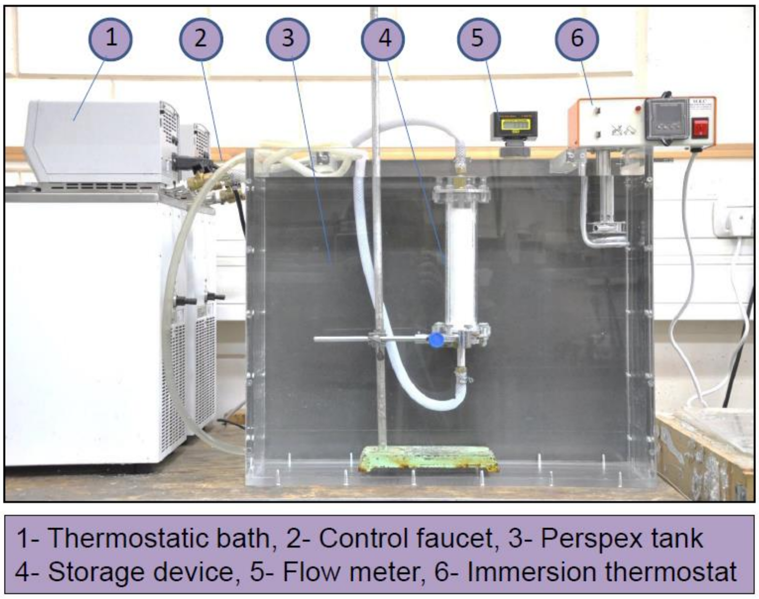
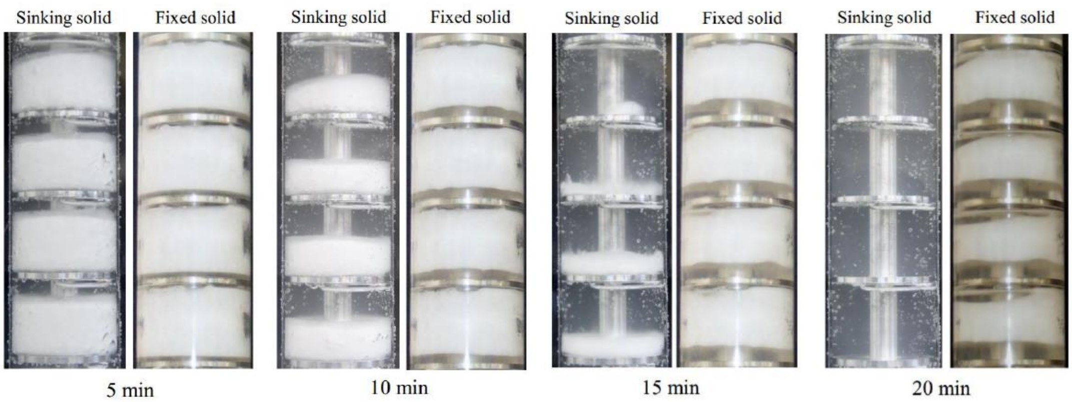


Figure 1. The experimental setup.

5 Results

Figure 2 shows the differences between regular and enhanced (close-contact) melting, and one can see that the melting time was 2.5 times shorter in the method developed in the present study, whereas the temperature difference between the heat transfer fluid and the storage material was the same. Moreover, novel theoretical and numerical models have been developed for close-contact melting, as shown in Figure 3.

- Melting time without CCM is 42 min
- Melting time with CCM is 18 min



$$\Delta T = 20\ ^{\circ}\mathrm{C}$$

Figure 2. Typical melting vs. enhanced close-contact melting achieved in this study.

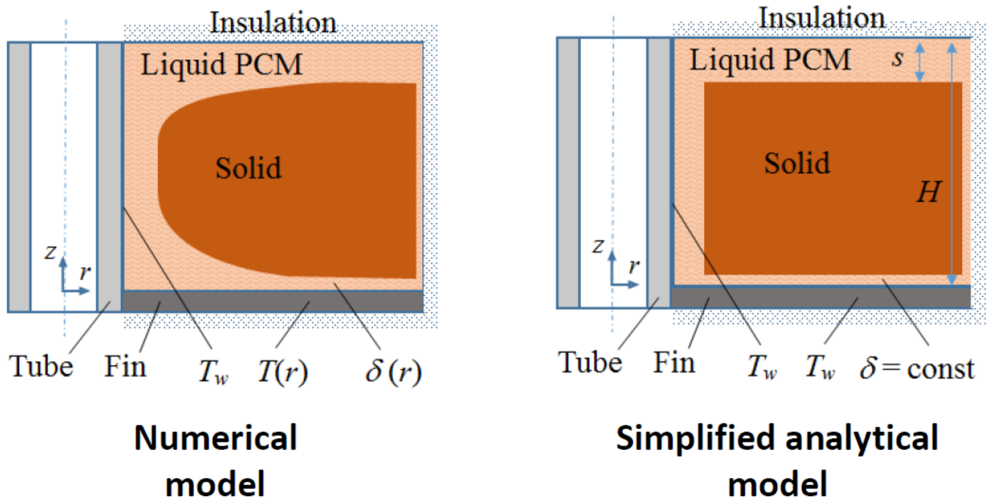


Figure 3. Novel in-house models developed in this study.

6 Outcomes or future work

This secondment has laid a foundation for the future visit of ESR24 (Yoram Kozak) from BGU to Auburn University (September-October 2014). His main tasks include “fusion”, both experimentally and theoretically, of the expertise on close-contact melting that he brings from BGU, with the know-how accumulated in Auburn on nano-enhanced PCMs.

7 References

Y. Kozak, T. Rozenfeld, **G. Ziskind** (2014) Close-contact melting in vertical annular enclosures with a non-isothermal base: theoretical modeling and application to thermal storage. *Int. J. Heat Mass Transfer* **72**, 114-127.

Y. Kozak, T. Rozenfeld, **G. Ziskind**, New developments in modeling of close-contact melting, *Proceedings of Eurotherm Seminar 99: Advances in Thermal Energy Storage*, Lleida, Spain, 28-30 May 2014.

T. Rozenfeld, Y. Kozak, R. Hayat, **G. Ziskind**, Phase-change processes in concentric finned storage units, *Proceedings of Eurotherm Seminar 99: Advances in Thermal Energy Storage*, Lleida, Spain, 28-30 May 2014.

T. Rozenfeld, Y. Kozak, **G. Ziskind**, Heat Transfer Enhancement in Latent Heat Storage Units, *Proceedings of 11th AIAA/ASME Joint Thermophysics and Heat Transfer Conference, AIAA Aviation and Aeronautics Forum and Exposition 2014*, Atlanta, GA, 16-20 June 2014.

T. Rozenfeld, Y. Kozak, **G. Ziskind,** Enhanced melting in geometries suitable for thermal energy storage, accepted for presentation at *15th International Heat Transfer Conference,* Kyoto, Japan, 10-15 August 2014.

8 Assessment

The agreement between the numerical predictions and experimental findings is very good both in terms of the total melting time and instant melting patterns, observed and simulated. The findings are compared with simplified analytical models which account for the CCM only. These models make it possible to obtain theoretical expressions for the melt fraction and heat transfer rate, allowing for their representation in a dimensionless form. Thus, the governing dimensionless parameters of the problem are revealed and generalization of the results becomes possible. To summarize, a good foundation for the future research is achieved.

Mechanical Engineering Seminar Series

AUBURN UNIVERSITY

Tuesday, June 24, 2014
2:00 pm
ME Conference Room 1409 Wiggins Hall

Heat Transfer and Enhanced Melting in Geometries Suitable for Latent-Heat Thermal Energy Storage Systems

Dr. Gennady Ziskind
Department of Mechanical Engineering
Ben-Gurion University, Negev, Israel

ABSTRACT

This seminar deals with recent developments in modeling and experimentation of solid-liquid phase change processes, with special attention to the geometries commonly encountered in or suggested for the latent-heat thermal energy storage (LHTES) systems, which use phase-change materials (PCM). Due to geometry, the processes in these systems are multi-dimensional and complicated, and include phenomena such as convection in the liquid phase, sinking of solid in the liquid, and volume change because of phase change. Thus, their reliable modeling requires significant efforts and experimentation in this field is quite difficult and could lead to results rather different from those characteristic of thermal-storage applications.

SHORT BIO

Dr. Ziskind earned his M.Sc. and D.Sc. degrees from the Faculty of Mechanical Engineering at the Technion-Israel Institute of Technology. He served for four years as a tenured Principal Research Engineer with the Energy Engineering Center at Technion and has been an Associate Professor and the Head of the Heat Transfer Laboratory at Ben-Gurion University. His research focuses on various aspects of heat and mass transfer and multiphase systems, including passive cooling techniques, phase change and aerosol mechanics. Ziskind's current research areas include phase-change energy storage and thermal management. He has co-authored 50 journal articles and more than 80 conference papers.

REFRESHMENTS WILL BE SERVED

For additional information, please contact Jay Khodadadi (334-844-3333) or P.K. Raju (334-844-3301)