INNOSTORAGE IRSES-610692	Deliverable number:	D7.2
	Title:	Report on Staff Exchange

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
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Contents

1 Objectives

The main objective of the secondment is to combine mutually complementary expertise of the two groups – Close-contact melting (CCM) and Nanostructure-enhanced Phase Change Materials (NePCMs). The goal of this project is to explore, both theoretically and experimentally, the effects of nanoparticles on melting processes where the solid bulk is unfixed and can sink towards a hot surface. The project is related to Tasks 3.1, 3.2, 4.1 and 4.2. A secondary goal is to discuss further collaboration and share different ideas for research.

2 Introduction

The main advantage of Phase-change Materials (PCMs) is that the heat is stored and released at constant temperature, a most important advantage for building applications. The main limitation in the use of PCM lies in overcoming the problem of low thermal conductivity: a liquid or solid layer which grows on the surface during melting and solidification, respectively, creates thermal resistance which reduces the heat transfer rate. In order to enhance the rate of heat transfer into PCMs, one of the most novel techniques is to disperse high-conductivity particles inside the PCM. This technique is called Nanostructure-enhanced Phase Change Materials (NePCM), and is expected to enhance the heat transfer rates due to the NePCM higher thermal conductivity compared to common PCM. The group from Auburn University has a wide experience in both modeling [1] and characterization of these materials [2].

Another way to enhance melting is by proper design of the storage unit. The group from Ben-Gurion University has showed that the melting rate can be enhanced by 2.5 times if the solid bulk is allowed to sink on the hot surface [3]. Actually, the phenomenon of a sinking solid bulk that melts directly on a hot surface is well known and called close-contact melting (CCM). A thin molten layer is formed between the solid and the hot surface, as the melt is squeezed to the sides by the descending bulk solid. Thus, PCM is melted continuously, keeping the flow in the thin molten layer. CCM allows high melting and heat transfer rates due to the relatively thin layer of liquid PCM, across which heat is conducted to the solid phase.

The current research will explore the effect of combination between CCM and NePCM. CCM allows close contact between the heat source and the solid NePCM, which leads to heat transfer processes that are dominated by heat conduction, and have a potential to maximize the advantages of NePCM thermal conductivity enhancement. The different effects of this combination will be explored both experimentally and theoretically.

3 Description of work

The CCM processes are investigated by performing experiments and numerical simulations, in which vertical cylindrical blocks of solid PCM, with different mass fractions of nanoparticles, are melted on a horizontal planar heat source maintained at a constant surface temperature. The experiments are recorded by a camera, allowing to calculate visually the melting rate. The experimental setup is designed using both groups' experience with CCM and

NePCM. Production and characterization of the NePCM samples is done by using the Auburn University group unique knowledge. The numerical modeling and theoretical analysis of the different physical phenomena are developed by the efforts of the two groups together.

4 Materials and Methodology

Small samples in the shape of a cylinder are made of eicosane, as shown in Fig. 1a, with different mass fraction of silver nanoparticles. Figure 1b shows the experimental setup, which includes a hot plate that is connected to a circulator. A Heat Transfer Fluid (HTF), with a temperature higher than the melting temperature, flows from the circulator through the hot plate. The sample is placed on the hot plate and melting starts almost immediately, as shown in Figure 1c. The entire process is tracked by a digital camera. The effects of the temperature of the hot plate and of the diameter-to-height ratio of the sample are also studied. This experimental setup will be able to show the difference in the melting rate between NePCM and pure PCM.

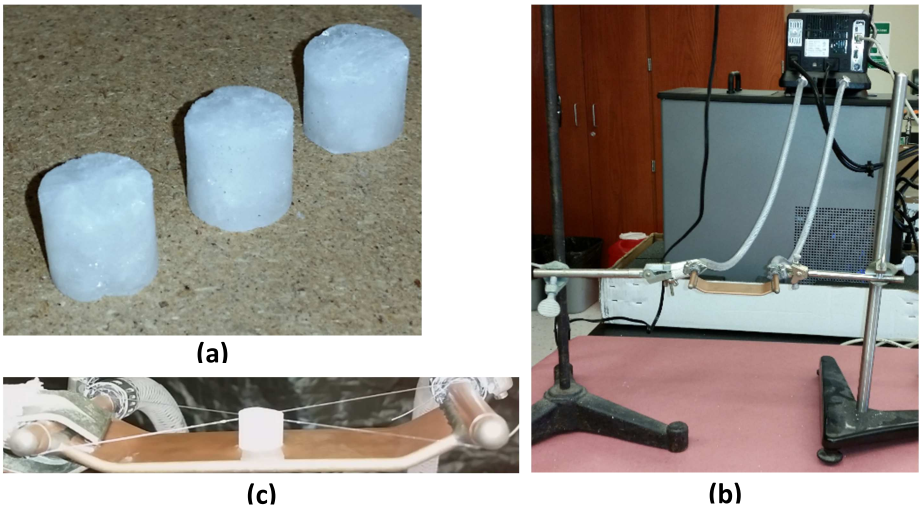

Figure 1. (a) Cylindrical samples made of pure eicosane, (b) The experimental setup, (c) A sample in the shape of a cylinder melting on the hot plate.

5 Results

Theoretical analysis using common and relatively simple modeling techniques [4,5] for both CCM and NePCM derived results that are general for different geometrical configurations. Figure 2a shows the improvement in the melting time with the nanoparticles concentration under different conditions. These results predict that, theoretically, there is a potential in the combination between CCM and NePCM. A model for the specific case of CCM with NePCM of a vertical cylinder on a plate with constant temperature was develped. Figure 2b shows the predicted melting rate, for a case study, of a cylinder made of NePCM with different nanoparticle concentrations.

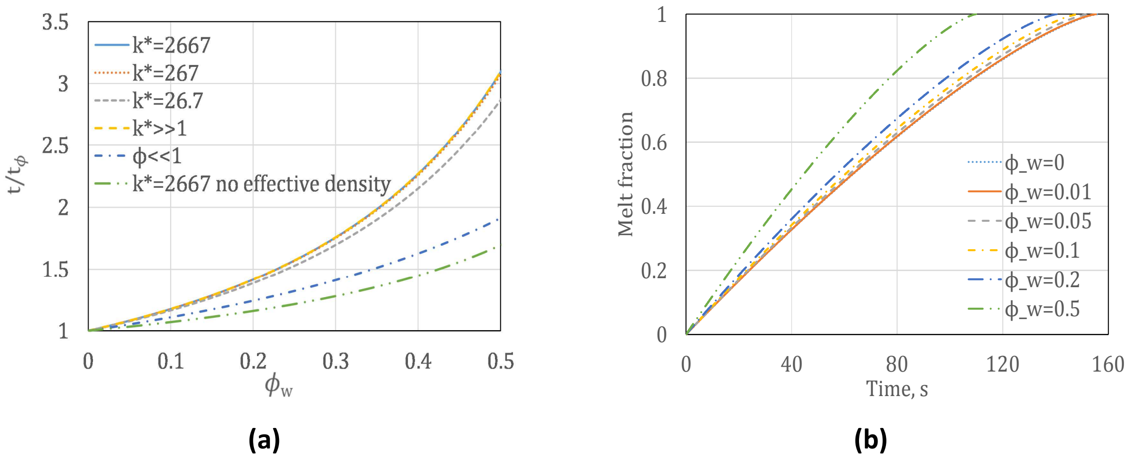

Figure 2. (a) The improvement in the melting time due to the nanoparticles for different cases, (b) The melt fraction for a vertical cylinder with different nanoparticles' concentrations.

6 Outcomes or future work

This is an ongoing research, and by the end of the secondment experimental results are expected, for both pure PCM and NePCM, that will allow comparison with the theoretical model predictions. This work can be developed further, for other geometries and with more elaborate modeling techniques.

7 References

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8 Assessment

The secondment gave me an opportunity to work, exchange ideas and discuss with one of the world-leading groups in phase-change materials study. The collaboration enriched my world-view and opened my mind to new ideas. I have learned much from both the experimental and the theoretical aspects of the field. Not only that new frontiers in PCM research were explored in this collaboration, but this secondment allowed me to expand my own horizons.