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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	Signature and date
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1 Objectives

The main objective of this secondment is to design a new high temperature shell and tube PCM system with dynamic melting. Other possible collaboration projects will also be discussed during this secondment.

2 Introduction

Dr. Steven Tay was awarded a three years fellowship from the Australian Renewable Energy Agency (ARENA) from Dec 2012 to Dec 2015. The main focus of his fellowship is to research on dynamic PCM systems for high temperature thermal energy storage. The collaboration work with GREA enables him to make use of GREA's high temperature thermal energy storage test facility, the only one available in the world, to conduct several experiments that are relevant to his fellowship. A new shell and tube heat exchanger with the capability for the dynamic melting technique will be designed during Dr. Steven Tay's stay in GREA. The new design will then be built and tested by GREA after the secondment. The work to be conducted will lead to joint journal papers. Other projects where collaboration could be made will also be discussed during Dr. Tay's secondment in GREA.

3 Description of work

A new concept of heat transfer enhancement for a tube-in-tank phase change thermal energy storage system was investigated experimentally by Tay et al. [1]. Melted paths in the frozen PCM are created using pre-melt tubes. This melted PCM is then recirculated using a pump. The flow of the melted PCM causes mixing and increases the overall heat transfer. This technique is referred to as dynamic melting. Dynamic melting can reduce the amount of the heat transfer area which can increase the compactness factor and therefore improves the energy storage effectiveness. The other advantage of dynamic melting is that the PCM is continually mixed when in the liquid state, which is a well-established method that prevents phase segregation [2, 3], and therefore potentially avoid PCM degradation. An application for dynamic melting is for an off-peak refrigeration system where there is considerable time available for freezing and the cooling is needed in a short period of time during the day.

The work described earlier was conducted for low temperature applications (below zero degrees Celsius). In this project, the dynamic melting technique will be implemented in a high temperature PCM storage system experimentally. This test will be conducted in GREA's high temperature test facility. Paraffin PCM with a phase change temperature of 58 °C was selected, while Syltherm 800 (synthetic oil) has been selected as the heat transfer fluid (HTF).

4 Methodology

In previous research [4-6], Dr. Tay and his team have empirically demonstrated that the effectiveness-number of transfer units (ε-NTU) can be used to characterise the heat transfer in

a PCM thermal storage unit (TSU) with a tube-in-tank type arrangement. The experimental investigation demonstrated that the heat exchange effectiveness, defined by the phase change temperature, strongly correlated with the number of transfer units (NTU). A computational fluid dynamics (CFD) model of a tube-in-tank PCM system has been developed and validated through experimental results by Tay et al. [6, 7]. It was found that the heat transfer through the PCM is essentially one dimensional. Therefore, a mathematical model was developed by Tay et al. [8] and experimentally validated based on the ε-NTU technique for tubes in a phase change thermal energy storage system. The characterisation enables any design to be evaluated as to whether the storage system can deliver the required temperatures for cooling in a building, and therefore enable the correct design specifications of a PCM storage system [9].

In this project, the ε-NTU technique is used to design the proposed shell and tube heat exchanger system. Using this technique, the total length of the tube in a known PCM volume, to achieve certain effectiveness can be determined. It was decided that the effectiveness of the system should be between 0.2 and 0.45 for the range of the flow rates to be tested. This requirement is to ensure that there is sufficient “rooms for improvement”, so that the effect of dynamic melting can be clearly seen. The heat exchanger is then designed using Solidworks software. This model will then be imported into CFD software known as ANSYS. A CFD model will be developed to analyse the flow distribution of the HTF. Several designs on the locations of the inlet and outlet ports were analysed and the best design will be selected for the construction of the prototype.

5 Outcomes or future work

The focus of this secondment is to design and analyse the flow distribution of the new heat exchanger system. Due to the time constraint, the results of the flow distribution analysis could not be completed during the secondment period. The analysis will continue after the secondment has been completed and the final design will be sent to GREA for approval before GREA arranges for it to be constructed for testing. The testing will be conducted by the personnel from GREA and results will be discussed with Dr. Tay and his team. A joint publication will be produced on this work.

There are also other projects that have been discussed during this secondment. These are shown below.

1) Experimental validation and parametric study using a CFD model for Active Slab System
2) CFD analysis on existing high temperature heat exchanger with Sodium Nitrate as PCM
3) Comparison of UniSA’s dynamic PCM system with DLR’s dynamic PCM system

6 References

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[5] Tay NHS, Belusko M, Bruno F. Experimental investigation of tubes in a phase change thermal energy storage system. Appl Energy. 2012 2;90(1):288-97.

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[8] Tay NHS, Belusko M, Bruno F. An effectiveness-NTU technique for characterising tube-in-tank phase change thermal energy storage systems. Appl Energy. 2012; 91:309-19.

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7 Assessment

This secondment has given me the opportunity to work with world-leading international researchers in the field of phase change thermal storage. The experience gained in this collaboration work will also enable me to design and build the prototype required for my fellowship.