University of Victoria | Graduate Studies

Notice of the Final Oral Examination for the Degree of Doctor of Philosophy

of

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MSc (Technical University of Delft, Netherlands, 2013)
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"Characterization, Experimentation and Modeling of Mn-Fe-Si-P Magnetocaloric Materials"

Department of Mechanical Engineering

Thursday, October 25, 2018
9:00 A.M.
Clearihue Building
Room B007

Supervisory Committee:
Dr. Andrew Rowe, Department of Mechanical Engineering, University of Victoria (Supervisor)
Dr. Mohsen Akbari, Department of Mechanical Engineering, UVic (Member)
Dr. Jens Bornemann, Department of Electrical and Computer Engineering, UVic (Outside Member)

External Examiner:
Dr. Mohamed Balli, Department of Physics, University of Sherbrooke

Chair of Oral Examination:
Dr. Doug Magnuson, School of Child and Youth Care, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

The objective of this work is to assess the potential of Mn-Fe-Si-P for magnetic heat pump applications. Mn-Fe-Si-P is a first order transition magnetocaloric materials made from save and abundantly available constituents. A significant magnetocaloric effect occurs at the transition temperature of the material. The transition temperature can be tuned by changing the atom ratios to a region near room temperature.

Mn-Fe-Si-P in magnetic heat pumps is investigated by determining the materials properties, 1D system modelling and experiments in a magnetic heat pump prototype. We characterize six samples of Mn-Fe-Si-P, based on their heat capacity and magnetization. The reversible component of the adiabatic temperature change is found from the entropy diagram, and compared to cyclic adiabatic temperature change measurements. Five of the six samples are selected to be formed into epoxy fixed crushed particulate bed, which can be installed into a magnetic heat pump prototype.

A system model is constructed to understand the losses of the magnetic heat pump prototype. Several experiments are performed with Gd with rejection temperatures around room temperature. Including dead volume and casing losses improves the modeling outcomes to match the experimental results closer.

Experiments with Mn-Fe-Si-P are performed. Five materials are formed into modular beds that can combined into two layer configuration. Six experimental configurations are tested, one single layer regenerator test with a passive lead second layer, and five experiments using two layers with varying transition temperature spacing between the materials. The best performance of the beds was found at close spacing at suitable rejection temperatures. It was found that at far spacing the performance of stronger materials would produce a lower temperature span than that of weaker materials at close spacing.

The experimental results provide results that are used to validate the system modeling approach using the material data obtained of the Mn-Fe-Si-P samples. We integrate material properties into a system model. A framework is proposed to take into account the hysteresis. This framework shows an improvement of the predicted trend for a single layer case. The proximity of simulation and experimental multi-layering results are dependent on the rejection temperature. At the higher end of the rejection temperature the modeling results over predict

the temperature span around the active region. At lower rejection temperatures the simulation under predicts the experimental temperature span. The inclusion of experimental pressure drop improved the trends found at higher rejection temperatures. A further improvement was found varying the interstitial heat transfer term. Modeling future research should focus on characterizing the thermo-hydraulic closure relationships for crushed particulate epoxy fixed beds, and improvements to the heat loss model.

Mn-Fe-Si-P is able to produce a temperature span, when a suitable set of Mn-Fe-Si-P materials are selected based on minimal hysteresis. Making it a viable material for magnetic heat pump applications. The performance of Mn-Fe-Si-P is further improved by layering materials with closely spaced transition temperature. Future research should focus on increasing the production of Mn-Fe-Si-P materials with low hysteresis, and improving the regenerator matrix geometry and stability.