University of Victoria | Graduate Studies

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

of

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MSc (Shiraz University, 2011)
BSc (Shiraz University, 2008)

“Material Screening and Performance Analysis of Active Magnetic Heat Pumps”

Department of Mechanical Engineering

Monday, April 24, 2017
9:00 A.M.
Engineering Office Wing
Room 106

Supervisory Committee:
Dr. Andrew Rowe, Department of Mechanical Engineering, University of Victoria (Supervisor)
Dr. Mohsen Akbari, Department of Mechanical Engineering, UVic (Member)
Dr. Phalguni Mukhopadhyaya, Department of Civil Engineering, UVic (Outside Member)

External Examiner:
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Dr. Mary Lesperance, Department of Mathematics and Statistics, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

With the discovery of the magnetocaloric effect, utilizing magnetocaloric materials in cycles to generate cooling power began. The magnetocaloric effect is a physical phenomenon observed in some magnetic materials where the temperature of the material increases and decreases with application and removal of magnetic field. Usually the adiabatic temperature change observed in magnetocaloric materials is too small for room temperature refrigeration. A solution to this problem is to use magnetocaloric materials in an active magnetic regenerator (AMR) cycle.

In this study a detailed numerical model is developed, validated, and used to improve our understanding of AMR systems. A one dimensional, time dependent model is used to study the performance of an active magnetic regenerator. Parameters related to device configuration such as external heat leaks and demagnetization effects are included. Performance is quantified in terms of cooling power and second law efficiency for a range of displaced fluid volumes and operating frequencies. Simulation results show that a step change model for applied field can be effectively used instead of full field wave form if the flow weighted average low and high field values are used. This is an important finding as it can greatly reduce the time required to solve the numerical problem. In addition, the effects of external losses on measured AMR performance are quantified.

The performance of eight cases of known magnetocaloric material (including first order MnFeP1-xAsx and second order materials Gd, GdDy, Tb) and 15 cases of hypothetical materials are considered. Using a fixed regenerator matrix geometry, magnetic field, and flow waveforms, the maximum exergetic cooling power of each material is identified. Several material screening metrics such as *RCP* and *RC* are tested and a linear correlation is found between *RCPMax* and the maximum exergetic cooling power. The sensitivity of performance to variations in the hot side and cold side temperatures from the conditions giving maximum exergetic power are determined. The impact of 2 K variation in operating temperature is found to reduce cooling power up to 20 % for a second order material, but can reduce cooling power up to 70% with a first order material.

A detailed numerical analysis along with experimental measurements are used to study the behavior of typical FOM material (MnFeP1-xSix samples) in an AMR. For certain operating conditions, it is observed that multiple points of equilibrium (PE) exist for a fixed heat rejection temperature. Stable and unstable PEs are identified and behavior of these points are analysed. The impacts of heat loads, operating conditions and configuration losses on the number of PEs are discussed and it is shown that the existence of multiple PEs can affect the performance of an AMR significantly. Thermal hysteresis along with multiple PEs are considered as the main factors that contribute to the temperature history dependent performance behavior of FOMs when used in an AMR.