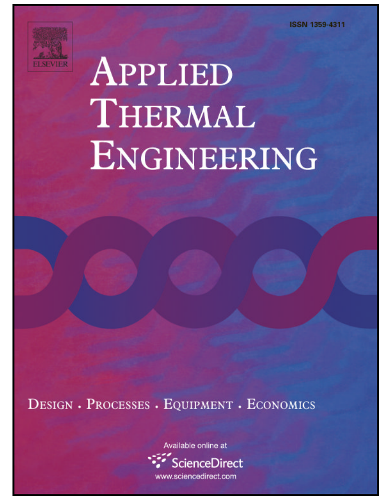
# Accepted Manuscript

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PII: S1359-4311(18)30867-6
DOI: https://doi.org/10.1016/j.applthermaleng.2018.06.007
Reference: ATE 12278

To appear in: *Applied Thermal Engineering*

Received Date: 6 February 2018
Revised Date: 10 May 2018
Accepted Date: 3 June 2018

Please cite this article as: I. Mugica, S. Poncet, J. Bouchard, An Open Source DNS solver for the simulation of Active Magnetocaloric Regenerative cycles, *Applied Thermal Engineering* (2018), doi: https://doi.org/10.1016/j.applthermaleng.2018.06.007

# An Open Source DNS solver for the simulation of Active Magnetocaloric Regenerative cycles

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**Abstract**

This paper describes the development of a new versatile multiphysics solver, whose final objective is to characterize Active Magnetocaloric Regenerative (AMR) cycles. The description is followed by a thorough validation divided in two parts. First, the separate simulations of the constituent physics are validated (porous geometry generation, fluid flow, Conjugated Heat Transfer and magnetic field). Then, the whole AMR code is compared to a measured prototype. The results are in all cases close to published numerical or experimental data. Also, two coupling mechanisms are studied, the temperature dependency of the viscosity of the Heat Transfer Fluid (HTF), and the influence of the magnetic permeability on the internal magnetic field of Gadolinium metal. Both effects prove to be negligible to compute the temperature field of a Magnetic Regenerator (MR). Moreover, by neglecting these effects the magnetic and flow fields of the MR can be computed beforehand, which reduces substantially the computational load at run time. Finally, the speed-up of the parallel multiphysics solver is evaluated.

*Keywords:* Magnetic refrigeration, multiphysics solver, Active MagnetoCaloric Regenerative, porous medium, parallel computing

## 1. Introduction

Part of the general research on refrigeration technology is focused on the development of alternative refrigeration cycles to the well established vapor-compression technology. The objective of this research domain is to minimize the drawbacks of vapor-compression cycles, which include: ozone depletion potential, toxicity of refrigerants, noise, and energy consumption. Several alternative technologies have been ranked by Goetzler (2014) attending to their potential to substitute vapor-compression cycles. The likeliness for substitution was weighted by the criteria of energy savings and development status. The first five technologies in the ranking include: Elastocaloric (or Thermoelastic), Evaporative desiccant, Membrane Absorption, and Magnetocaloric cycles. It is yet unclear which could be the next mass marketed technology, as they all require further research.

This publication focuses on Active Magnetocaloric Regenerative (AMR) cycles, where the working refrigerant is a solid with magnetocaloric properties. Kitanovski et al. (2015) recently published a book that covers most of the engineering aspects surrounding this technology. Similar to vapor-compression, AMR cycles use a phase transition to create a thermodynamic cycle based on Magneto-Caloric Materials (MCM). This magnetic phase transition happens around the Curie temperature of the material ($T_C$), where relatively small variations of temperature or magnetic field cause a transition between para- and ferromagnetic states. This magnetic phase transition abruptly changes the entropy state of an MCM. As a consequence other thermodynamic properties, such as heat capacity, experience an abrupt change too. This effect modifies the thermal equilibrium of the MCM with its environment, causing the Magneto-Caloric Effect (MCE). Predominantly, when the internal magnetic field of an MCM increases, its temperature increases too and vice versa (although there are some MCMs with an inverse effect, see Krenke et al. (2005)).

The temperature increase (or decrease) produced by the MCE is generally too small to be used in conventional refrigeration cycles . Aprea et al. (2015b) esti-

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