Paper: Comparison magnetic profiles

Introduction

- Problem definition
    - Increased regulations on the use of refrigerant fluids motivate the study of caloric effects
        - Pp. 49-51 Thesis
        - See Lionte 2018 for a summary on problems of other refrigerants
    - Magnetic refrigeration is the most advanced of available caloric technologies, especially for wine coolers and air conditioners
        - P. 51 Thesis
        - With small temperature span
            - Justifying the use of fixed temperatures with small span
                - Table 1 COBEM paper
- Characterization of MR
    - Materials and effect
        - Cite Smith for a comprehensive review
    - Regenerators
        - cf. pp.80-81 of thesis for simple explanation of regenerators and the use of multi-layer regenerators
- Components of a MR
    - p.53 thesis
    - Cite Trevizoli 2016 review
- Basic functioning of a MR

- Cycle steps
- What needs to be studied?
  - “Eriksen (2016) highlights...”
    - p.55 thesis
  - Interactions between components are modelled as waveforms that are exchanged between models
    - In particular, the magnetic profile is “generated” by the magnetic circuit and passed to the AMR model
  - Show basic profiles that will be studied
    - Waveforms are identified by the transition between constant states
      - “Instantaneous”: instantaneous variations
      - “Ramp”: ramp-like variations
      - The rectified cosine is just the waveform
- Literature review on profiles and cycles
  - Cf. Section 2.3 of Thesis
    - Tusek, Plaznik, Kitanovski
  - Trevizoli 2015
  - My DTU paper
    - Effects of blow duration on the performance, for a given magnetic profile
    - Shorter blow fractions that focused the fluid flow during periods of higher magnetic field increase cooling capacity but decrease coefficient of performance (due to larger velocities and hence higher pumping power)
    - No study of the waveforms (in terms of shape)
  - Nakashima, Teyber

Also duration of blows, but no study of the types of profiles

The fluid flow profile can be more easily investigate with experimental methods

Here we focus on the magnetic profile, to aid in the design of magnetic circuits (subject of future papers)

Which question I'm trying to answer?

Which magnetic profile results in the largest cooling capacity?

Which magnetic profile results in the largest coefficient of performance?

This paper will present a parametric study of different magnetic profile waveforms and their effect on the two performance metrics for a magnetic refrigerator: cooling capacity and coefficient of performance

To emulate constraints on an operating point of actual magnetic refrigerator devices, the temperature span is set fixed

And hence, we do not talk about second-law efficiency

Materials and Methods

In this work, we perform numerical simulations of a previously developed AMR model, varying the profile and geometric parameters. We also couple a model for calculating valve power, something that is understudied in the literature

With this, we can evaluate the influence of the profile on cooling capacity and coefficient of performance

AMR model

Governing equations

Casing losses

Cite paper where it is explained

The term can be neglected

How the fluid flow profile is used

- Convergence loop on the momentum equation
- Separate solution to speed up computation
  - Properties evaluated at an average temperature between hot and cold source temperature
  - Interpolated tables exported from EES
  - 80/20 %vol solution of water/ethylene-glycol

How the magnetic profile is used

- Demagnetization correction
- Built-in method for the MCE
  - Section 4.2.2. Thesis
  - Calculated from tabulated data
- Magnetic profile as B = mu0 H
  - Calculated in free space, corrected with demagnetization

Utilization factor

- Eqs 2.71 e 2.72 Thesis

Calculation of cooling capacity

- Remember to change phrasing to avoid copy of Trade-offs paper

Calculation of magnetic power

- Remember to change phrasing to avoid copy of Trade-offs paper

Calculation of pumping power

- Remember to change phrasing to avoid copy of Trade-offs paper

Evaluation of fluid properties for the energy equation

- p. 164 Thesis

Evaluation of solid propeties

- Single layer regenerators
    - Section 4.2.2. thesis
- Multilayer
    - The energy equations do not change, only the method to calculate properties
    - Section 5.2 Thesis

Hydraulic system model

- Cite Thermag 2016 and 2018 papers for context on use of solenoid valves
- Due to developments in our group, two sets of valves were tested in these simulations
    - Section 4.3 Thesis
    - Section 5.3 Thesis

Calculation of COP

- Section 4.4 Thesis - remember to change

Definition of the fluid flow profile

- Section 3.1 Thesis verbatim

Definition of the magnetic profiles

- Complete abstraction from the magnetic circuit
- Can be generated either by a rotating permanent magnet
    - Cite Trade-off paper
- Or by a solenoid or superconducting circuits
    - Cite Katja Klinar, Teyber
- Examples
    - Rectified cosine

        - Instantaneous
        - Ramp
    - Why these 3 examples?
        - Commonly found in built devices in the literature
        - Easy to define mathematically
        - Characteristic of well established examples of magnetic circuits
            - Nested one pole Halbach cylinders
            - Reciprocating devices, or electromagnets
            - N-pole double cylinders

Results and discussions

- 2 stages of analyses

Comparison of cosine and instantaneous profiles using a simplified model

- Section 4.7.2 Thesis
- All these results are valid for one regenerator geometry and one temperature span
- Analysis of the instantaneous profile
    - Thesis 4.7.3
    - Restrictions on the width and length, varying height (in the same direction of field application)
        - Include a schematic diagram

In-depth analysis of the ramp profile using a multilayer AMR model with casing losses

- Based on better performance of the instantaneous profile
- Explain that, since we are using a more realistic profile, we incorporate losses and use multilayer regenerators

- Section 5.6 Thesis
- Explain fixed and variable parameters

Final remarks

- To the authors' knowledge, this is the first study where magnetic profiles for AMR model are mathematically modeled and the model parameters are changed in a systematic way
- The instantaneous profile yields higher cooling capacity, even by reducing the blow fraction on rectified cosine
    - Reduction to levels achieved by pumping and valving systems, mainly restricted by valve opening times
- The ramp profile is a feasible approximation for the instantaneous profile, and can be optimized for increasing cooling capacity
    - In particular, by synchronizing the plateau durations between fluid and magnetic profiles

Recursos extras do paper

- Organização e limpeza de dados
    - Organizar os dados em DataFrames
    - Tornar os dados disponíveis, juntamente com uma explicação detalhada do modelo matemático e sua implementação numérica
    - Pesquisar sobre FigShare e Zenodo para tornar tabelas disponíveis