Integration of a magnetocaloric heat pump in a low-energy residential building

BuildSim-Nordic 2017
EnovHeat Project

EnovHeat Project: creation of an innovative and efficient magnetocaloric heat pump for a single family house:

- COP of 5 or more

- 2.5 kW of heating power

- 30 K of temperature span between heat source and heat sink
Possibility for a single hydronic loop integration
Magnetocaloric Heat Pump

- System based on the magnetocaloric effect and active magnetic regenerator (AMR) technology

- Use reversible magnetocaloric effect of solid refrigerant to build a cooling / heating cycle

- Potential for high coefficient of performance, more silent operation and efficient part-load control.
Magnetocaloric Heat Pump Cycle

- Heat transfer fluid
- Magnetocaloric material

(a) Initial state with temperature gradient
Magnetocaloric Heat Pump Cycle

(b) Adiabatic magnetization
Magnetocaloric Heat Pump Cycle

(c) Cold-to-hot blow
Magnetocaloric Heat Pump Cycle

(d) Adiabatic demagnetization
Magnetocaloric Heat Pump Cycle

(e) Hot-to-cold blow
Magnetocaloric Heat Pump Cycle

(f) Back to initial state
Magnetocaloric Heat Pump

- 40 different lab prototypes of magnetocaloric devices in the world
- We have the best ones! (at DTU Risø, collaboration of the project)
- Only magnetocaloric device used as a heat pump
Magnetocaloric Heat Pump: Examples

POLO – UFSC – Brazil (collaboration with DTU Risø)
Magnetocaloric Heat Pump: Examples

"Maggi" (second prototype of DTU Risø)
Magnetocaloric Heat Pump: Examples

“MagQueen” (new prototype of DTU Risø for EnovHeat project)
Integration of the Vapor-Compression Heat Pump in a Single Family House in Denmark

Integration of a vapor-compression heat pump
Integration of the Magnetocaloric Heat Pump in a Single Family House in Denmark

Integration in a single hydronic loop with ground source and under-floor heating
Case Study Building

- Danish single-story house: 150 m²
- Low-energy design
  “class 2020”: 16 kWh/m².year
- Hydronic radiant under-floor heating system
- Horizontal or vertical ground source heat exchanger
- water-brine: 20 volume% ethylene glycol
Magnetocaloric Heat Pump Modeling

- 5-dimensional lookup table implemented in MATLAB with 1600 points
- Valves average power consumption measured on prototype
- Motor efficiency kept constant
- Pump work modeled with a polynomial from manufacturer’s data
Building Modeling

- Multi-zone model of the house in Simulink
- Explicit FVM for heat transfer in construction elements
- Similar to HAM-tool
- Nested MATLAB functions for hydronic elements with ε-NTU model combined with plug flow model
Results

Heating power production and usage of the magnetocaloric heat pump
Results

Heat pump COP and total system COP
Results

Four-month test of heating up a house
Results

Daily average COPs during the four-month heating test
Conclusion

- It works !!! (at least in the numerical simulation)

- Can deliver up to 2600 W of heating power with average seasonal system COP of 3.93

- Use of a vertical borehole as a heat source allows better performance

- However, often operates at part-load capacity which decrease total system’s COP (1.84)

- Demand side management strategies such as indoor temperature set point modulation for building energy flexibility, could be an interesting solution to improve the heat pump operation
Thank you for your attention!
Any questions?

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