4TU.Energy

Magnetic-Ionocaloric Heat Pump System

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Main Results and Impact

The project resulted in two critical outputs that advanced the idea from a hypothesis to a validated conceptual design. First, a Bachelor's thesis titled "Thermo- & Fluid Dynamic modelling of magnetic-ionocaloric heatpumps" validated the system's critical "regeneration" phase. A major scientific bottleneck in this technology is the efficient separation of magnetic particles from the ionic liquid solvent to "reset" the system after heat release. To rigorously validate this without the high risks of trial-and-error experimentation, a 2D numerical model using COMSOL Multiphysics was developed. This model coupled Fluid Dynamics (solving Navier-Stokes equations for laminar flow) with Magnetostatics to simulate the complex interplay between hydrodynamic drag forces and magnetic attraction. The study specifically investigated magnetic forces, simulating the trajectory of magnetic particles within a continuous flow channel subjected to a static permanent magnet placed beneath it. This computational approach allowed for the precise manipulation of variables such as channel geometry, fluid viscosity, and magnetic field strength, providing a depth of theoretical understanding that a simple physical prototype could not have yielded in the same timeframe.

The results of this modeling work provided the quantitative proof-of-concept requested by the reviewers regarding the system's feasibility. The simulations successfully demonstrated that a static magnetic field could create a distinct concentration gradient within the fluid, and evaluated the separation efficiency under different operating conditions (concentration difference between the clean supernatant and the particle-rich slurry). Crucially, the research identified flow velocity as the governing parameter, establishing a definitive trade-off curve between system throughput and separation quality; while lower velocities allow for near-perfect separation, higher velocities cause drag forces to overcome magnetic attraction. This work transitioned the separation concept from a qualitative hypothesis to a validated process with defined engineering constraints, proving that passive magnetic separation is a viable solution for the regeneration phase.

To bridge the gap between this fundamental physics and a deployable application, an Engineering Doctorate (EngD) team delivered a "Conceptual Design Document" for a Magneto-Ionocaloric heat pump tailored for domestic use. This output directly addressed the reviewers' concerns regarding the "state-of-the-art" by benchmarking our concept against existing vapor compression technologies. It provided the design of a full-scale system capable of extracting heat from a cold deposit and transferring it to a hot deposit for sustainable home heating.

Plan for follow-ups

This funding acted as a critical catalyst for "Community Building," enabling us to transition from a localized collaboration to a competitive European consortium. The seed funding allowed us to lay the necessary groundwork—specifically the modeling and design reports—which were instrumental in submitting a proposal to the prestigious Pathfinder Open Call.

Although the Pathfinder 2025 call didn’t work out for us; we were placed on the reserve list, a testament to the scientific quality achieved through this seed grant. We plan to utilize the detailed results generated here to resubmit to the Pathfinder Open Call this year. The 4TU.Energy funding essentially de-risked our high-risk, high-gain hypothesis, allowing us to prove the viability of our collaboration and compete at the highest European level.