



Thermo Magnetic Motor TMM

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Endurance Testing

The first generation *Thermo Magnetic Motor* (TMM) *K1* is the first of its kind that operates 24/7 in an industrial environment using low-temperature waste heat from a biomass power plant.

Specifications

- Rotor with blades made of thermomagnetic material (gadolinium)
- 10 stationary permanent magnets
- Hot (~60° C) and cold (~10° C) water supply
- 1 kW max. mechanical power output

The primary objectives were to demonstrate the conversion from waste heat into mechanical energy by utilizing the magnetocaloric effect (MCE) as well as the continuous operation under real-world conditions.



Figure 1. SBE container on the power plant site in Switzerland

After 20'000 operating hours the TMM *K1* is still running. Besides the findings of the endurance testing many valuable insights were gained which will impact future developments. The focus for the next-generation TMM is on performance and efficiency improvements.

Efficiency enhancements

- Using a material with high magnetocaloric efficiency (large magnetization change, low latent heat)
- Increasing the heat transfer between fluid and material
- Reducing the back-work ratio (BWR) by minimizing pressure losses

Efficiency Improvement

Major research and development steps are required towards an efficient and commercially viable TMM with a reasonable performance.

The laboratory-scale test facility *LabScale* allows studying the TMM process in detail, e.g., the heat transfer between the fluid and the magnetocaloric material as well as pressure and friction losses. Its flexibility and accessibility facilitates the testing of new setups and its full instrumentation allows measuring local phenomena as well as global characteristics.

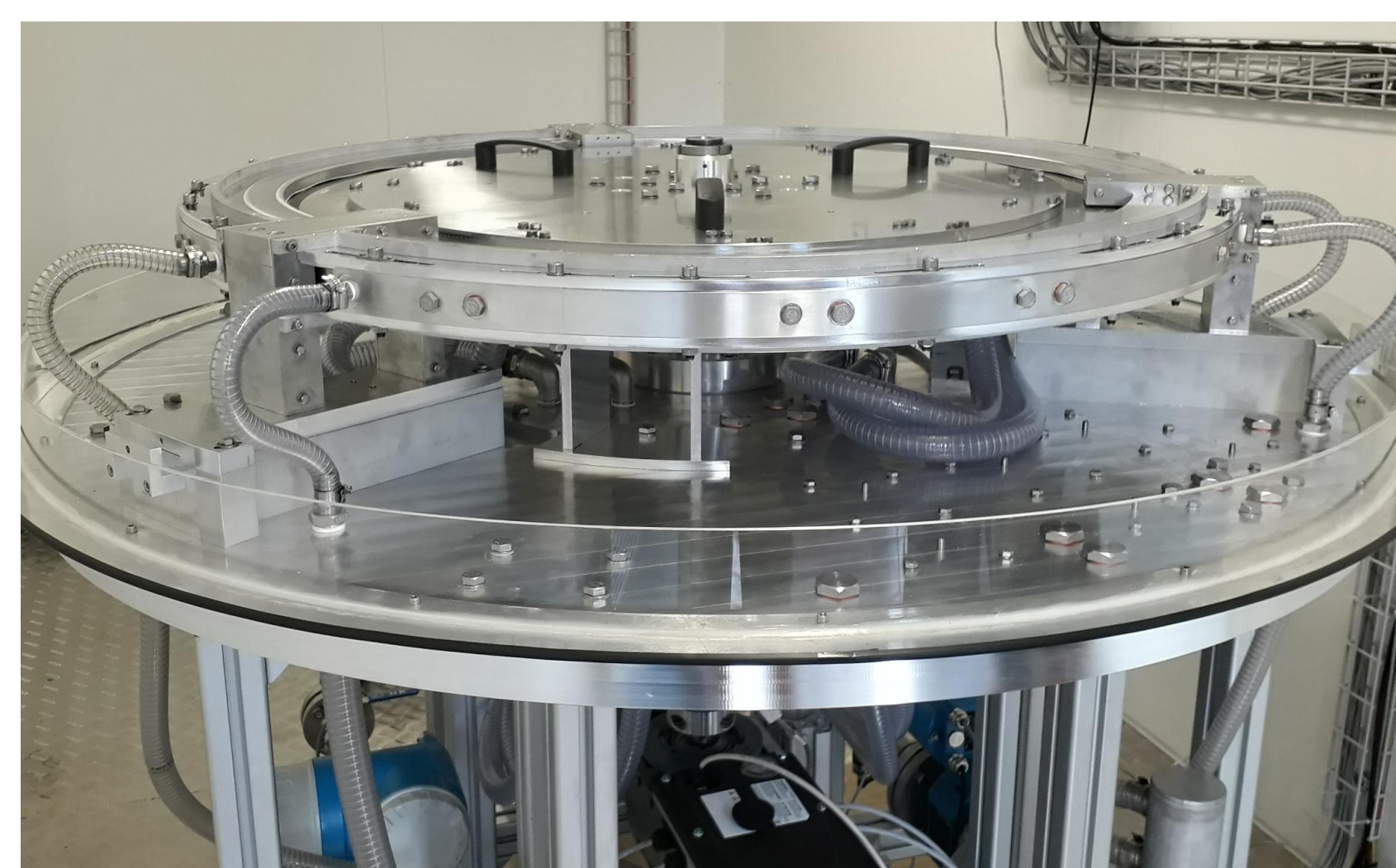


Figure 2. Laboratory-scale test facility *LabScale*

Currently available thermomagnetic materials limit the maximum possible efficiency to low values (thermal efficiency $\lesssim 1\%$) thus optimizing the cycle efficiency is very crucial. Certainly, new materials with better properties for this type of application are in demand for the long term.

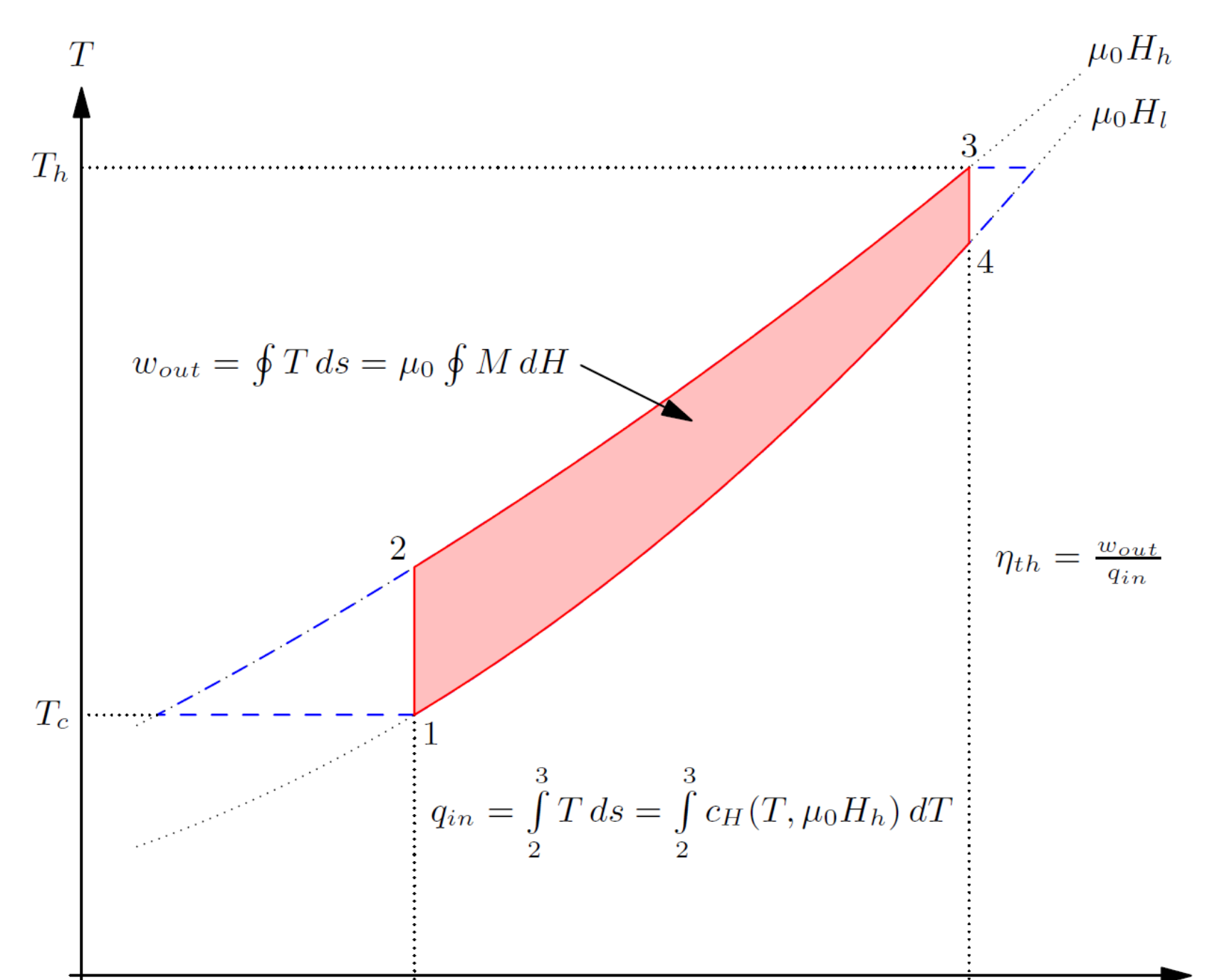


Figure 3. Ideal thermomagnetic BRAYTON cycle

Functional Model

The second generation TMM *K2* is currently being built which will be the first one with a substantial net power output in combination with a robust and compact design.

Still based on gadolinium (Gd) the new TMM will generate a net electrical power output in the kW range which requires significant development steps including design modifications and process optimizations.

Key development focuses

- Design improvements to achieve optimal utilization of the thermomagnetic material within the rotor and the permanent magnets on the stator side
- Optimizing the heat transfer between the hot/cold fluid and the thermomagnetic material while keeping the pressure losses reasonably low
- Compact and robust design as well as easy to operate (showcase model)

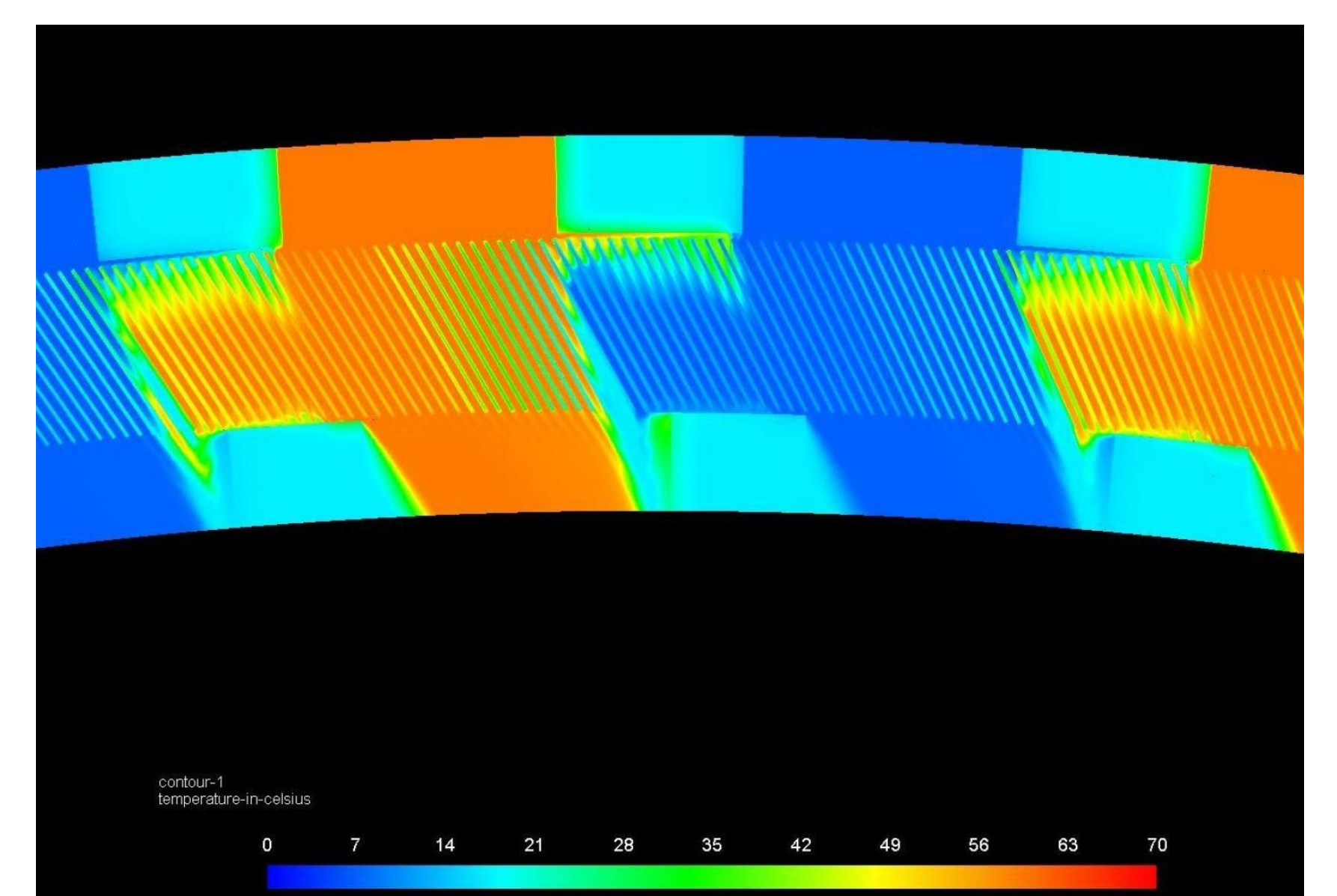


Figure 4. CFD analysis of rotor geometry with inclined blades

Summary/Outlook

- Endurance testing successfully completed
- Primary focus on efficiency improvements
- Research and development of next-generation TMM in progress
- Replacement of gadolinium by alternative magnetocaloric material with tailor-made properties as long-term goal

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