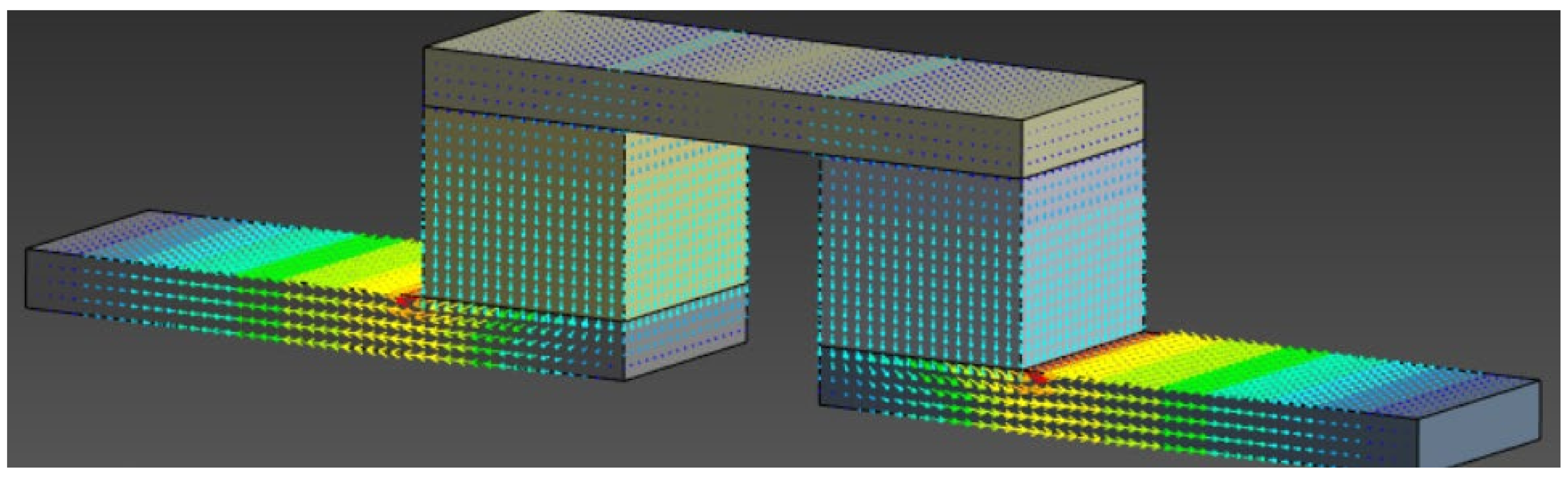
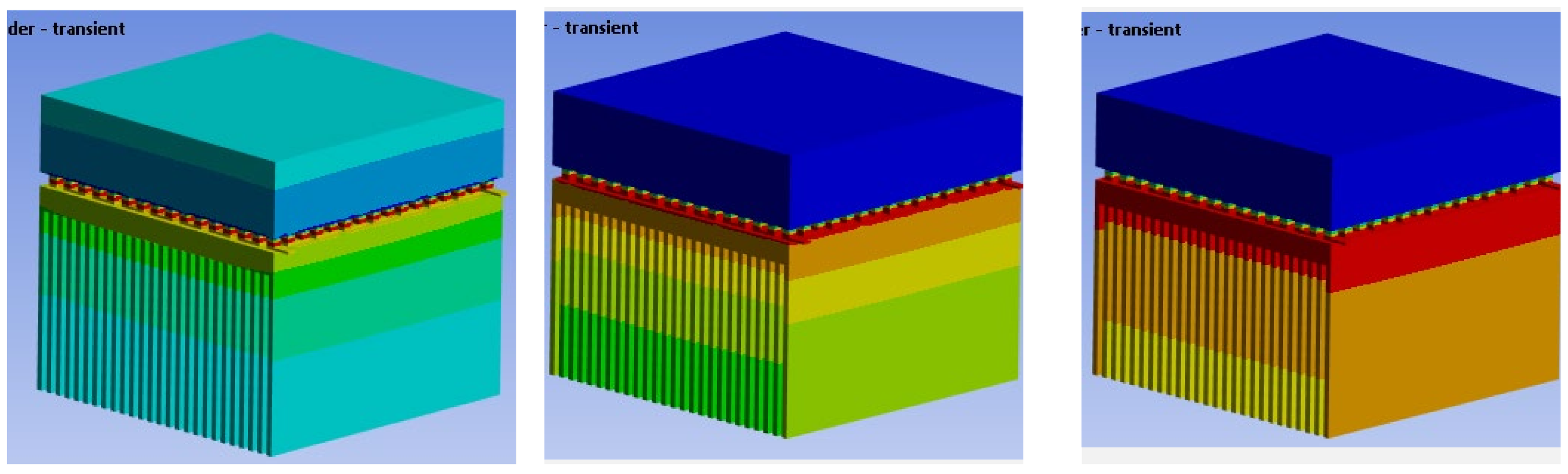
Technik & Architektur

Master Thesis – Energy and Environment

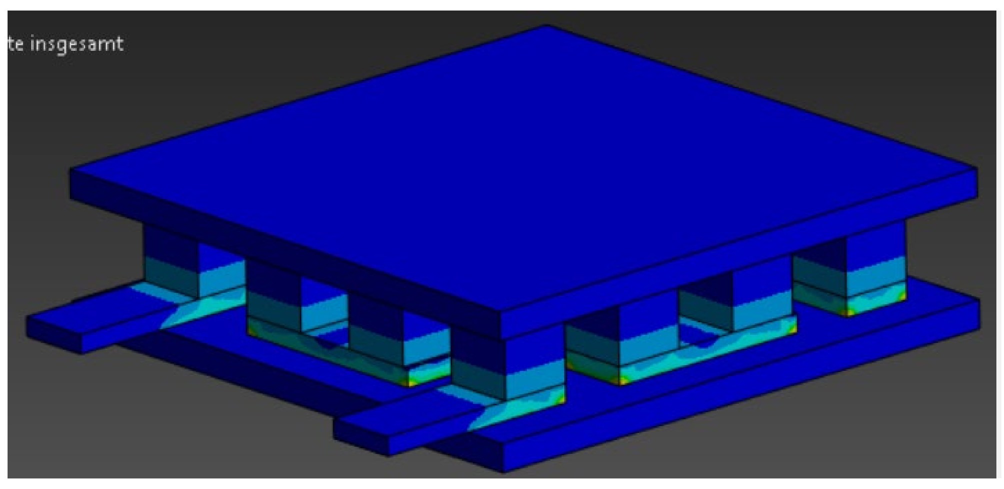
Modelling and Development of a Freeze Clamping System



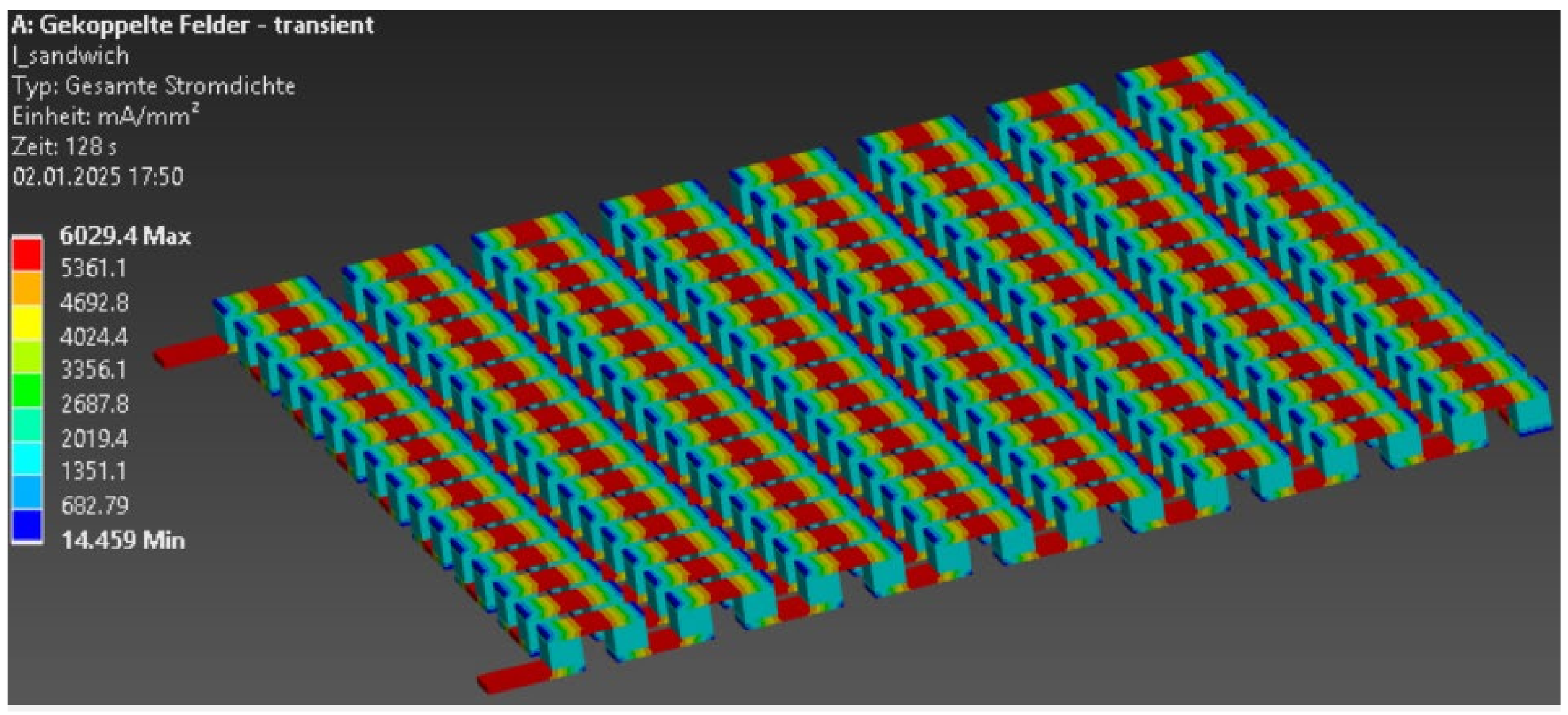
Thermocouple as the basic element of a thermoelectric cooler (Peltier element) with visualised heat flow.



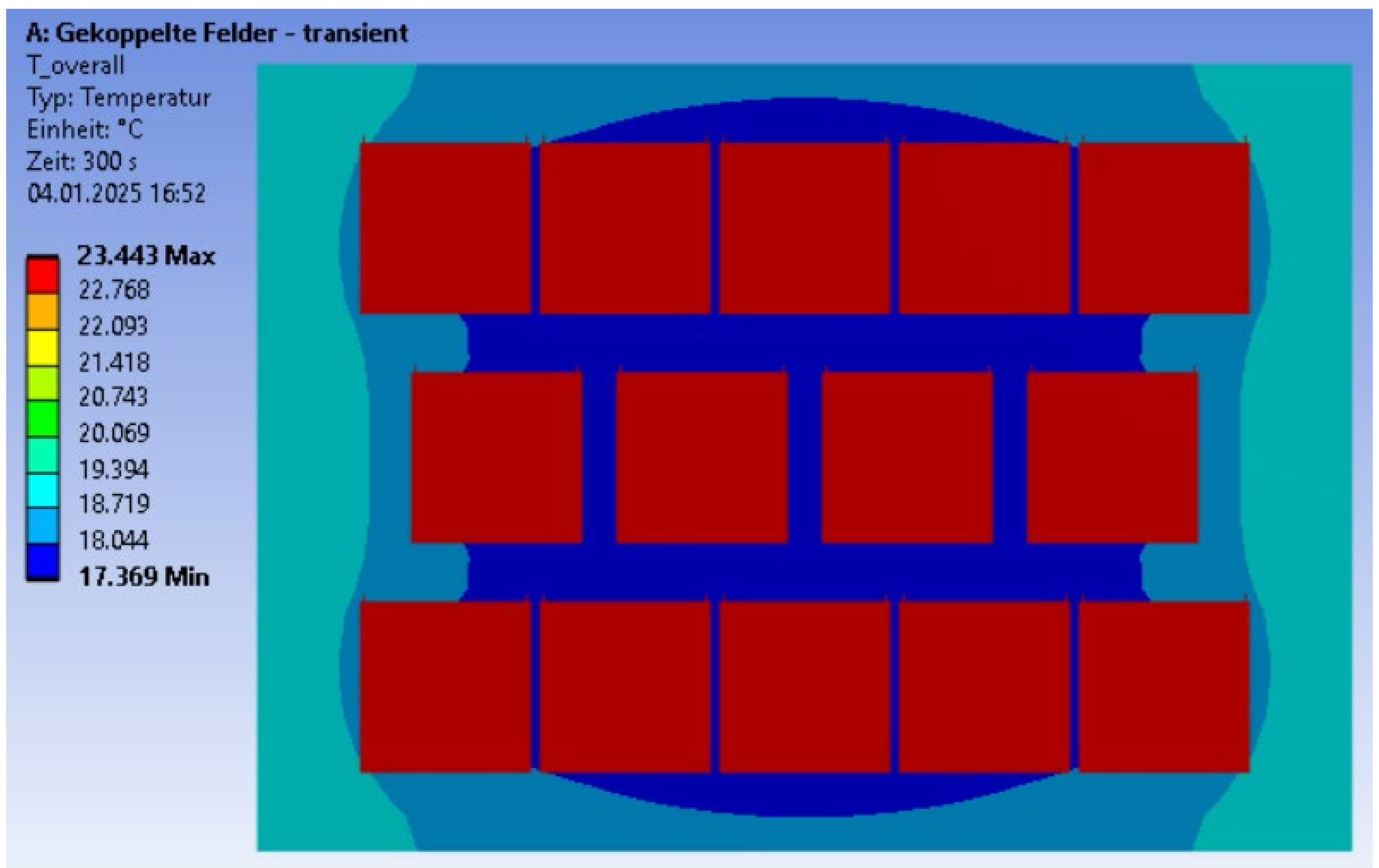
Visualisation of the temperature distribution of a system with Peltier elements in the course of a simulation.



Small version of a Peltier element with visualised heat flux density.



Transient simulation of a Peltier element array with visualisation of the total current density.



Temperature distribution on the underside of the stage with clearly visible Peltier elements and the influence of the Peltier element arrangement on the temperature distribution.

The aim of the work is the modelling and development of an innovative freeze clamping system based on thermoelectric Peltier elements. The challenge lies in the precise control of temperature differences, which are necessary to securely fix workpieces. Conventional clamping techniques reach their limits with small or sensitive workpieces, particularly in the watchmaking and medical technology sectors. In order to offer a sustainable and energy-efficient alternative, a numerical 3D model is being developed that realistically depicts the complex thermodynamic processes. Stationary and transient heat flows must be taken into account and validated against experimental data. The aim is to develop a system that combines high reliability with modular integration into industrial manufacturing processes.

The simulation model developed combines finite element analyses with experimental validation data to optimise the thermodynamic properties of the system. By iteratively adjusting material properties and convection conditions, the cooling capacity is maximised and energy efficiency is increased.

The simulation results show that material properties such as thermal conductivity and the Seebeck coefficient are decisive factors influencing the efficiency of the system. The developed model allows the precise calculation of temperature distributions and heat flows, both under stationary and dynamic conditions. Optimised convection conditions and adapted material parameters contribute significantly to the efficiency of the system. The simulation of transient thermoelectric phenomena enables a detailed analysis of the thermodynamic processes. The system provides a solid basis for future developments in production automation.

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MASTER OF SCIENCE
IN ENGINEERING