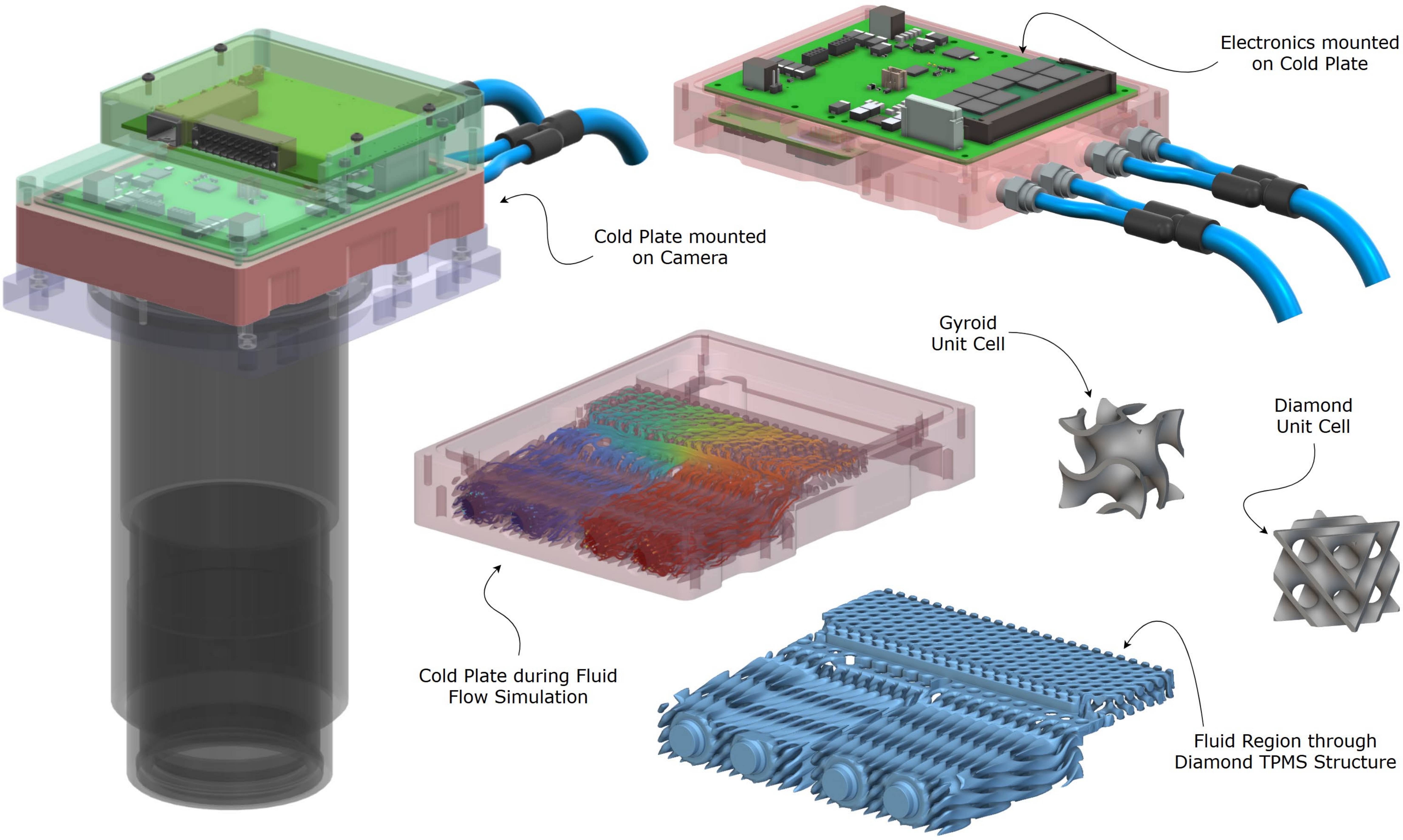
HSLU Hochschule Luzern

Technik & Architektur
Institute of Mechanical Engineering and Energy Technology (IME)
Master of Science in Mechanical Engineering

Master’s Thesis – Master of Science in Engineering

Implicit Heat Exchanger Design for Thermal Management

Enabling the Next-Generation of Heat Exchangers



Camera assembly featuring the optimized cold plate design with integrated TPMS-based Diamond structures

Problem Description

Modern electronic systems are experiencing a rapid increase in power dissipation, while the available design space for thermal management remains limited. Current advancements in electronic systems and the associated increase in power density lead to rising component temperatures and reduced reliability.

Conventional cooling solutions are reaching their performance limits in compact electronic systems. Next-generation heat exchangers are required to enable efficient thermal management in constrained design spaces.

Solution Approach

A design approach combining additive manufacturing and implicit modeling enables the development of advanced heat exchanger geometries. With the field-driven design capabilities of implicit modeling, lattice structures can be generated and tailored to specific channel geometries.

For thermal applications, Triply Periodic Minimal Surface (TPMS) structures are from special interest. They significantly increase surface area and improve convective heat transfer. Their smooth, continuous geometry promotes favorable flow behavior, making them well suited for fluid channel integration.

A simulation-based optimization workflow is developed to systematically evaluate the influence of TPMS topology on convective and hydraulic performance. This workflow enables informed decision-making and supports the identification of optimal design parameters.

This methodology is applied to the thermal management of a compact industrial camera system. The cold plate design is enhanced with internal TPMS-based fluid channels to improve thermal efficiency and reduce electric component temperatures.

Results

The developed approach significantly improves the thermal performance of the camera system.

The integration of TPMS-based cooling channels increases the internal surface area by up to 266%, enhancing convective heat transfer. The processor temperature is reduced by 51%, while other critical components meet their target temperature limits.

A key finding is the trade-off between performance metrics: higher heat transfer results in increased pressure drop. Diamond TPMS structures achieve the highest thermal performance, while Gyroid TPMS structures reduce pressure losses.

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