Topology Optimized Heat Exchangers for Additively Manufactured Electrical Machines

Summary

Additive manufacturing (AM) is evolving rapidly, and it is seen as an important step towards the next industrial revolution, being one of the key requirements for the decentralized production of highly complex structures. The flexibility of AM technology also allows the production of electromechanical components and electrical machines, which can have significantly better properties compared to conventionally manufactured devices. AM opens the possibility to utilize unconventional three-dimensional topology optimized structures, which allow the production of novel heat exchangers (HE) for electrical machines. However, currently there is no existing well-developed design methodology to realize these advantages. Therefore, this project focuses on the development of a design methodology for topology optimized HEs considering the advantages of AM. The objective of the project is the selection of an innovative electrical machine HE design, and the development of the optimization methodology. The practical part of the work involves validating the methodology in the lab by additively manufacturing (3D printing) the developed cooling solution and performing real-world measurements.

Research field:	Electrical power engineering and mechatronics
Supervisor:	Prof. Dr. Ants Kallaste
Availability:	This position is available.
Offered by:	School of Engineering Department of Electrical Power Engineering and Mechatronics
Application deadline:	Applications are accepted between June 01, 2025 00:00 and June 30, 2025 23:59 (Europe/Zurich)

Description

The research

Within this thesis, the PhD candidate will learn about the design and optimization of electrical machine cooling solutions. The main emphasis will be on the development of a design methodology based on topology optimization that considers the advantages of AM. We will provide the necessary software for numerical analysis, but the candidate will be responsible for developing and implementing the design procedure. A working prototype will be built and tested at the end of the thesis. The candidate will present his/her work at international conferences and publish journal papers required to complete the thesis within the PhD studies.

Responsibilities and tasks

- Selection the most suitable cooling method for AM
  - There are several different cooling system solutions for electrical machines. The task of the work is to select the one that benefits the most from AM's capabilities.
- Design methodology for electrical machine cooling
  - The possibilities of 3-dimensional geometrical freedom for building the HE will be studied, and the most effective solution will be chosen. The task is to work out the design principles of HEs and develop an effective design methodology.
- Topology optimization of the cooling system
  - Generating the geometry of the HE through numerical simulations and topology optimization algorithms. The task is to work out the design principles for numerical topology optimization and construct an effective simulation model.
- Practical tests on physical prototypes
  - Based on the developed design methodology a cooling solution will be manufactured and tested. The research goal will be the real-world verification of the developed methodology.

Applicants should fulfil the following requirements:

- A master's degree in electrical (preferably with focus on electrical machines) or thermal engineering, applied physics or mathematics.

- A clear interest in the topic.
- Excellent command of English.
- Strong writing and analytical skills.
- Capacity to work both as an independent researcher and as part of an international team
- Capacity and willingness to help with organizational tasks relevant to the project

The following experience is beneficial:

- Theoretical and experimental basics of heat transfer and electrical machines.
- Experience with computational fluid dynamics and numerical thermal models.
- Knowledge of mathematical optimization methods.
- Programming (e.g. Python, C, MATLAB).

The candidate should submit a research plan for the topic, including the overall research strategy. The candidate can expand on the listed research questions and tasks, and propose theoretical lenses to be used.

We offer:

- 4-year PhD position in the leading electrical machines research group in Estonia with a large portfolio of dedicated research, industrial and study-oriented projects
- The chance to do high-level research in one of the most dynamic Universities and research groups in the region
- Opportunities for conference visits, research stays and networking with globally leading universities and research centers in the fields of electrical machines and diagnostics

About the department

The Department of Electrical Power Engineering and Mechatronics of Tallinn University of Technology is an interdisciplinary research center that focuses on socially relevant and future-oriented research and teaching issues related to power engineering and mechatronics. The mission of the Department is to be a leader in electrical engineering and technical studies and development projects in Estonia, known and valued in society, and a respected partner in both national and international cooperation networks and organizations.

The department educates future energy leaders and engineers at the bachelor's, master's and doctoral level. Through training courses, the department ensures lifelong learning and continuous development.

The department carries out large-scale interdisciplinary scientific research, development and professional projects, thanks to which the competence in the field of electrical energy and mechatronics continues to grow. With research, application and development services, the department increases the competitiveness of companies in both the domestic and international markets, keeping knowledge in Estonia. The department has coordinated or been a partner in numerous international projects, such as Horizon 2020, INTERREG, 7FP, Nordic Energy Research, etc.

The Department of Electrical Power Engineering and Mechatronics conducts research within seven research groups and operates state of the art laboratories with high end equipment, offering also accredited services in the fields of lighting and different electrical measurements.

The departments' focus areas are related to both domestic and global developments, such as increasing digitalization and decarbonization, decentralization and decentralization of electricity generation, and the increasing use of renewable energy sources. The department conducts research in the following relevant areas tackling the energy transition:

- optimization of electrical systems and system analysis to find possibilities for electrification and decarbonization
- diagnostics and monitoring of equipment and systems
- cyber security, 5G data communications and artificial intelligence
- energy networks and research on hydrogen technologies, including energy storage, renewable energy, low carbon technologies, consumption management, IoT applications in energy
- implementation of smart industry, including industrial robotics, automation, 3D printing, machine vision
- implementation of energy and resource efficiency, including digitization of supply chains, mapping of opportunities to optimize systems and reduce energy consumption
- development of smart city solutions, including environmentally friendly and self-driving vehicles / drones, digital twin applications.

Additional information

For further information, please contact Prof. Ants Kallaste ants.kallaste@taltech.ee or visit https://taltech.ee/en/electrical-machine-group

To get more information or to apply online, visit https://taltech.glowbase.com/positions/974 or scan the the code on the left with your smartphone.