Optimization of Additively Manufactured Electrical Machines

Summary

Additive manufacturing as a production technology opens new horizons in the optimization possibilities of electrical machines. Through various optimization algorithms improvement in machine performance characteristics as well as power density can be achieved. It is possible to optimize the magnetic circuits through which a maximal usage of magnetic material can be achieved, resulting in a low material waste technique to increase the power density of the electrical machines. Different lattice structures can be used in the magnetic circuit in order to assure constructional strength. In addition, lattice structures can be utilized in electrical machines teeth and poles, significantly improving the performance characteristics. However, there is a lack of knowledge on how these criteria can be fed to optimization algorithms. Also, there are no standard procedures, which would help to simplify and accelerate the optimization tasks and which would be described and matured enough to be implemented in industrial processes. In the project optimization methodology for electrical machines will be developed that would consider the advantages of additive manufacturing. The optimization will concentrate on optimizing the machine torque density and minimizing the losses in the machine. The optimization will be carried out together with prototyping and by validating the optimization model.

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, 2022 00:00 and June 30, 2022 23:59 (Europe/Zurich)

Description

Within this thesis, the PhD candidate will learn about the additive manufacturing of electrical machines and design and optimization of special types of electrical machines. The main emphasis will be on the development of topology optimization procedure of electrical machine core construction considering the advantages of additive manufacturing. We will provide necessary hardware and software for simulation and prototyping the machines. The candidate is responsible for developing and implementing the optimization procedure. At the end of the thesis, several prototype machine will be built and the candidate will participate in this process. 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

- Primary design of 3D printed electrical machine
  - Reluctance machine (stepper machine) will be studied and construction of the machine will be selected and designed. The starting point of the design will be defining the nominal parameters of the machine, geometry of the stator and rotor and winding configuration. The machine will be constructed and tested.
- Optimization tools
  - Different optimization methods will be studied and best ones will be selected. Limitations and complexity of the algorithms are investigated. Selected algorithms will be implemented in Matlab environment.
- Geometrical optimization
  - Additive manufacturing is opening new ground for innovation in construction of electrical machines. The candidate will have to carry out an optimization of the magnetic material distribution using numerical or analytical analysis and optimization methods. The optimization objectives can be average torque, torque ripple, mass, power density and the efficiency.

- Material optimization

- Additive manufacturing allows printing different materials with different characteristic and with different porosity. For this optimization proses have to be developed considering different materials and introducing higher material porosity in the areas where the magnetic material has only constructional purposes. The optimization should consider the magnetic material volume distribution within 3D aiming to minimize eddy current and hysteresis losses. The optimization could be carried out as a multi-objective task taking into account other objectives.
- Optimized solution and design principles of 3D printed electrical machines
  - Final optimization procedure for 3D printed electrical machines have to be developed and 3D printed design principles have to be presented.

Applicants should fulfil the following requirements:

- a master's degree in electrical engineering (preferably with focus on electrical machines)
- a clear interest in the topic of the position
- excellent command of English
- strong and demonstrable writing and analytical skills
- capacity to work both as an independent researcher and as part of an international team
- capacity and willingness to help in organizational tasks relevant to the project

The following experience is beneficial:

- Theoretical and experimental basics of electrical machines
- Knowledge of advanced electrical machine design theory
- Programming in C++/ MATLAB
- Knowledge in CAD software's
- Knowledge in finite elemental calculations
- Working knowledge of optimization theory
- Basics of vector calculus and linear algebra

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/532 or scan the the code on the left with your smartphone.