MITSUBISHI ELECTRIC R&D CENTRE EUROPE

1, ALLEE DE BEAULIEU, CS 10806
35708 RENNES CEDEX 7, FRANCE
TEL. (+33) 02.23.45.58.58 – FAX (+33) 02.23.45.58.59

PhD Thesis proposal (3 years) M/F

Reference DITFT039

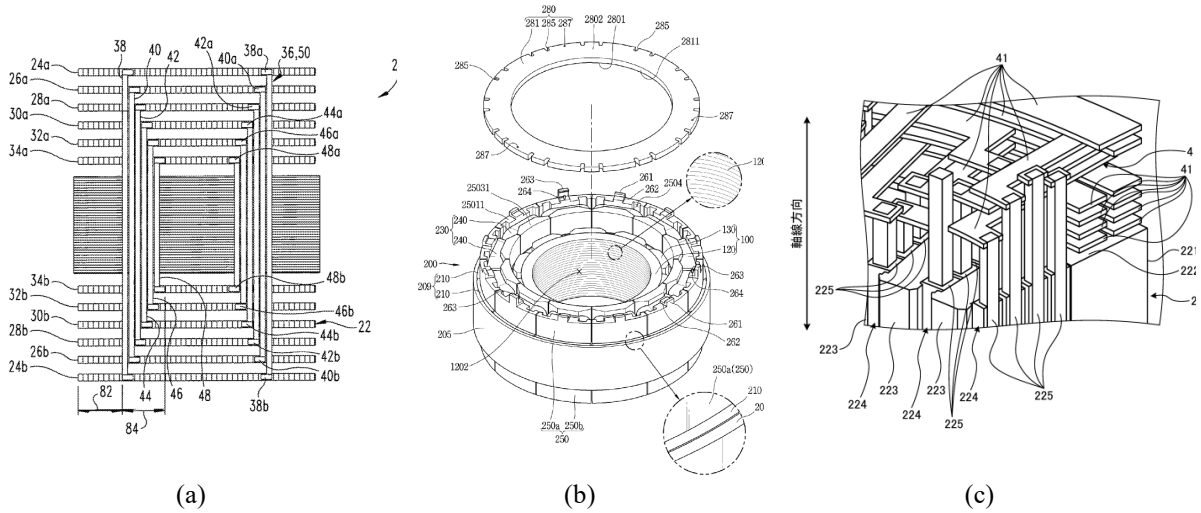
Permanent Magnet Synchronous Machine with PCB Stator: Design and Characterization

PhD Thesis supervisors:

Mitsubishi Electric R&D Centre Europe**:** Maxime Bonnet, Researcher
GREAH, Le Havre: Georges Barakat

Overall context

Medium-power permanent magnet synchronous motors (PMSM) (around ten kW) are widely used in fields such as the automotive and rail industries. The performance expected from PMSM is increasingly demanding: higher torque density, reduced volume and weight, higher efficiency, higher voltage levels, etc.
Power integration is an undeniable lever for improving the power density of the entire conversion chain, from the power supply to the motor, via the cooling system. In this context, power integration means sharing the cooling system and the space between the various components in the electrical conversion chain. However, this integration is accompanied by specific constraints on the motor in terms of volume and heat extraction. To address these issues, new motor winding structures are being developed. Among these structures, a technology based on PCB windings and applied to radial flux motors is being developed at Mitsubishi Electric R&D Centre Europe (MERCE).
The PhD will be carried out in collaboration with the GREAH (Groupe de Recherche en Electrotechnique et Automatique du Havre). The candidate will be required to travel regularly between Le Havre and Rennes.



(a) (b) (c)

Fig. 1 : Example of PCB windings for radial flux motors at ABB [1] (a), LG Electronic [2] (b) and Toyota Motors [3] (c)

Thesis subject

The PhD work will include an initial experimental phase relating to thermal aspects. This experimental stage will establish a law of dependence between current density and sample temperature. The abacuses thus obtained can be used as a reference for the pre-sizing of these motors.
This work will be complemented by a second theoretical component concerning field modelling and winding theory. Magnetic field modelling will include saturation to avoid overestimating motor performance. A more detailed calculation of losses and inductances will be required to characterize the motor after sizing. With PCB windings, coil structures made impossible by manufacturing constraints become feasible. The part of the PhD devoted to winding theories will include a theoretical study of new types of windings and the connection of coil heads.
The final objective of the PhD is to use the results of the models and measurements to develop a sizing method for PCB stator motors. An optimized prototype of a PCB- winding PMSM will then be designed to complete the thesis work.

Detailed objectives / organization

The thesis will take place in MERCE and GREAH premises (main location: LE HAVRE and stays at RENNES: business trips paid by the company) and will entail the following tasks:

- Study the state-of-art for motor windings, magnetic field modelling and motor sizing technics
- Experimental thermal measurements to create PCB windings thermal abacus
- Building a model for winding design
- Development of a sizing process
    - Magnetic field model with saturation
    - Calculation of electrical parameters
    - Losses calculation
    - Sizing process
- Design, manufacture and measurements of an optimized prototype
- Redaction of quarterly reports
- Redaction and publication of scientific papers
- Redaction of the thesis manuscript
- PhD defence

Prerequisites

- Engineer/Master degree with interest in research;
- Skills in electrical machines and electromagnetism are expected.
- Basic knowledge of thermal engineering is appreciated.
- He/she should be comfortable with mathematics and low-frequency electromagnetic modelling.
- The candidate is expected to have a pronounced taste for analytical modelling.
- Strong interest in experimentation, and familiar with basic electrical engineering lab equipment. (Power supplies, Scope, Power analyser, etc)
- The candidate will be required to use finite element software. Initial experience with these programs (FEMM 4.2, Flux 2D, Ansys, JMAG or ComSol) would be a plus.
- Autonomous, but team player.
- English: spoken / written.

Duration: 3 Years - Period: from September 2025 to September 2028

Contact: Magali BRANCHEREAU (jobs@fr.merce.mee.com) + Maxime BONNET (m.bonnet@fr.merce.mee.com)

Thanks for providing us an application letter and your CV mentioning the reference DITFT039.

References

[1] Mikail R., Pan Z., Englebretson S., “Windings for an electric machine”, ABB Schweiz AG, US Patent US10951080B2, filed Aug 20, 2018, and issued Mar 16, 2021.

[2] Chang-Heum Cho, Myunggeun Lee, Jangwon Lee, Shin Youngcheol, “Electric Motor”, LG ELECTRONICS INC, KR Patent KR20230071546A, filed Nov 16, 2021, and issued Jan 17, 2024

[3] 健裕 小森 Takehiro Komori, 観 赤津 Kan Akatsu, 享大 中村 Yukihiro Nakamura, “Mechanical and electrical integrated motor unit”, TOYOTA MOTOR CORP; NAT UNIV YOKOHAMA, JP Patent JP2023174375A, filed May 27, 2022, pending since Dec 7, 2023