〈2023年度 工学研究科〉　博士学位論文の要旨および審査結果

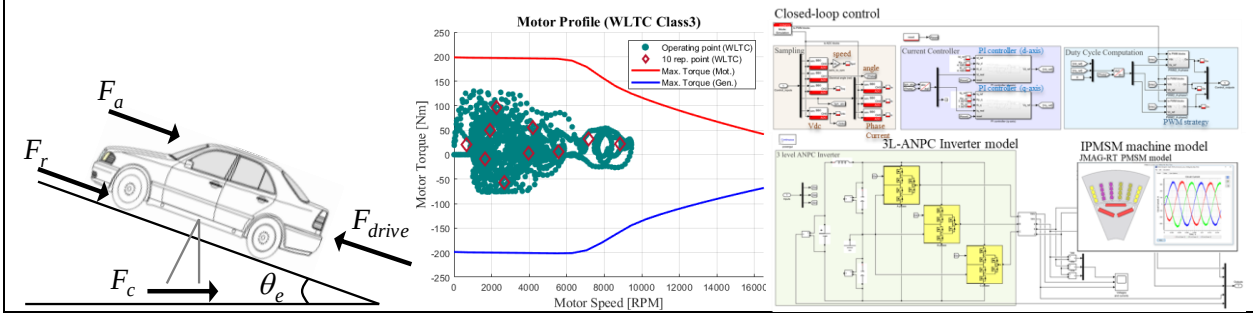
氏　名	KWAK Jaedon（かく　じぇどん）
学位の種類	博士（工学）・甲（課程博士）第 2 号
博士論文題目	Inverter-machine parametric co-design for energy efficient electric drive system
審査委員	(主査)　FUKUSHIMA Hiroaki
	(副査)　IMAI Tadayuki, PIUMARTA Ian, CASTELLAZZI Alberto, NAKAMURA Taketsune (Kyoto University)

論文の概要

Motor-drives are the underpinning technology of many pivotal elements of societal infrastructure, ranging from energy generation to air-conditioning to electric transportation. As such, they represent one the main utilization ways of energy in electrical form. In view of the increasing electrification level of our society, attempts to improve efficient energy usage should target the improvement of motor drive systems.

A motor-drive system comprises of an electrical machine and some electrical circuit (power converter) that drives it. Traditionally, the design of the machine and the power converter have been carried out stand-alone. However, such approach does not allow for the overall system optimization under all possible operational scenarios. Significant improvements can only be obtained by joint design of the two elements in consideration of the actual load conditions. So, this study aimed at developing a comprehensive integrated design and optimization framework and at delivering experimental proof-of-concept demonstration of its benefits in a relevant case-study application. It is a very timely and original undertaking, with high potential for significant impact within the specialist academic and industrial community.

The starting point is the identification of a meaningful case-study (e.g., electric vehicles) and define the analytical equations, which fully describe its operation. Based on them, a so-called *mission profile,* which summarizes torque and speed requirements of the machine. Specifically, such mission profile needs to be reduced to a manageable number of representative points, which represent its gravity center, and mapped onto output voltage and current requirements for the inverter. Once the reduction exercise completed, the next aim is to carry out an iterative multi-dimensional design of the drive system, using jointly machine and inverter design parameters within a unified environment. Finally, the original approach in this thesis is to carry out the design optimization incorporating the additional information of *how long* (in time) a given operational condition is applied for: in electrical terms, that means optimizing the design for *energy efficiency*, as opposed to power efficiency and implies a key perspective shift on the way to improving operational efficiency in general and, for instance, extending battery drive range .



論文審査結果要旨

The thesis included a balanced mix of theoretical, analytical and computer-aided-design methodologies and culminated in a phase of extensive experimental demonstration. It considered two very timely case-studies, consisting of a hybrid starter-generator system and a fully electric vehicle, relying on very different battery voltages (400 and 800 V) and featuring different operational requirements.

In addition, it carried out a thorough and comprehensive multi-parametric design and optimization framework development, highlighting the possibility to reduce the study to a subset of most significant parameters, by deploying design of experiment (DOE) methodologies.

For both case-studies, a detailed inverter and machine design was proposed, including state-of-the-art technological solutions for both components. For the inverter, a 3-level active-neutral-point (3L-ANPC) topology was considered, in consideration of realistic technology transfer to and adoption by industrial partners. A silicon implementation was benchmarked against a more innovative silicon-carbide one, highlighting the benefits and routes to cost compensation for the latter, new semiconductor technology.
For the machine, a permanent magnet type with surface integrated magnets was considered, corresponding to actual solutions currently deployed industrially for these applications.

Finally, experimental tests delivered convincing proof-of-concept demonstration of the validity of the proposed innovation.

口頭試問結果要旨

At the defense, the applicant was evaluated from scientific, theoretical, technical, and industrial points of view. The examiners confirmed that the applicant had appropriate knowledge, skills, and experience in his field of specialty. The applicant's achievements include in total 2 peer reviewed journal papers and two international conference presentations. Based on all the above points, the thesis examination committee made a decision that Jaedon KWAK deserves to receive a Doctor of Engineering degree from KUAS