

# **Lifetime Assessment and Robustness Validation for Automotive Electrical Traction Machines**

**Daniel Gerhard Huger**

Vollständiger Abdruck der von der Fakultät für Elektro- und Informationstechnik der Universität der Bundeswehr München zur Erlangung des akademischen Grades eines

**Doktor-Ingenieurs (Dr.-Ing.)**

genehmigten Dissertation.

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Die Dissertation wurde am **05.12.2016** bei der Universität der Bundeswehr München eingereicht und durch die Fakultät für Elektro- und Informationstechnik am **29.03.2017** angenommen. Die mündliche Prüfung fand am **02.05.2017** statt.



Forschungsberichte Elektrische Antriebstechnik und Aktorik

Band 26

**Daniel Huger**

**Lifetime Assessment and Robustness Validation  
for Automotive Electrical Traction Machines**

Shaker Verlag  
Aachen 2017

**Bibliographic information published by the Deutsche Nationalbibliothek**

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at <http://dnb.d-nb.de>.

Zugl.: München, Univ. der Bundeswehr, Diss., 2017

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Printed in Germany.

ISBN 978-3-8440-5340-1

ISSN 1863-0707

Shaker Verlag GmbH • P.O. BOX 101818 • D-52018 Aachen

Phone: 0049/2407/9596-0 • Telefax: 0049/2407/9596-9

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# Abstract

In the course of this work, lifetime prediction, testing and robustness validation specifically for electrical traction machines are covered. The concept of physical modeling – a combination of analytical multi-physics machine behavior models and lifetime models for machine components which allows lifetime prediction for a specific load and application – is investigated. For several machine components (bearings, magnets, winding, insulation, resin, lamination), lifetime models including physical interactions are set up and parametrized with accelerated lifetime tests.

In the first part basic lifetime and robustness assessment concepts are presented and common temperature-based lifetime models are discussed. A qualitative approach to failure analysis based on chains of effects and classification of possible machine failures is given and useful machine life in terms of key machine parameters is defined.

In the second part lifetime models for bearings, NdFeB magnets, wire insulation, resin and lamination are given. All relevant failure causes, amongst others temperature, temperature cycling, moisture, vibration, mechanical and impact load, voltage and chemical deterioration are investigated, failure mechanisms are discussed and their modes and effects are described. The electromagnetic and thermal machine behavior is modeled analytically and interactions and mutual reactions - also caused by aging - are included (for example relations between coil and magnet temperature, magnet aging and thermal derating). Results for an exemplary machine, application, load and environment are discussed.

The third part covers lifetime tests and model parametrization. An optimization method for temperature cycling tests is given which allows reducing the test duration. Methods for optimizing entire test procedures for lifetime testing and robustness validation are discussed in terms of time and cost savings. Temperature and temperature cycling tests are performed on various types of magnets, lamination (glued and welded), winding (distributed and concentrated), insulation and resin (various resins, casting and impregnation processes). The test results are used to parametrize lifetime models given in the second part.



# Acknowledgments

The research covered in this thesis has been carried out between the years 2011 and 2016 at the *Chair of Electrical Drives and Actuators, University of Federal Defense Munich*, Germany, in cooperation with *Robust Design, AUDI AG*, Ingolstadt, Germany. I wish to use this opportunity to express my sincerest thanks and gratitude to all those who contributed to and supported this work at every opportunity.

First, I am deeply indebted to my supervisor and Head of Chair Prof. Dr.-Ing. Dieter Gerling, who rendered this work possible after all by giving financial support as well as countless valuable comments and encouragement. The perfect balance between technical guidance and great scientific latitude allowed for excellent working conditions.

I further wish to express my gratitude to the secondary supervisor Prof. Dr. techn. Norbert Seliger, *University of Applied Sciences Rosenheim*, Germany, for sharing his profound knowledge in lifetime assessment and failure mechanisms and furnishing the Second Opinion.

Besides, I wish to thank the Audi department I had the pleasure to work in, and all other Audi colleagues for their great financial support and shared expertise. Special thanks go to Sebastian Witt for countless encouragements, endless contributions and fruitful discussions. I am also much obliged to Jan Richnow and Dr. Tobias Menke for their generous support concerning lifetime testing.

In addition, I will always remember the remarkably pleasant working environment and great support at the Chair. My warmest thanks go to Johann Mayer, Hans-Joachim Koebler, Benno Lange and Harald Hofmann, just to name a few.

My special gratitude goes to my parents for their enormous support in all situations; you made this work possible.

Finally, I wish to express my deepest and warmest thanks to Janine for her unlimited understanding and encouragement; this thesis is dedicated to you.





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