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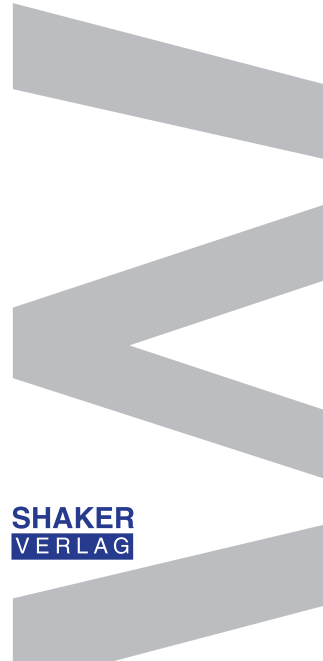
Marcel Waldhof

Scalable Design of Axial Flux Machines for Personalized
Wearable Robotics



Band 16

**SHAKER
VERLAG**



**Scalable Design of Axial Flux Machines for Personalized
Wearable Robotics**

**Von der Fakultät Informatik, Elektrotechnik
und Informationstechnik der Universität Stuttgart
zur Erlangung der Würde des Doktor-Ingenieurs (Dr.-Ing.)
genehmigte Abhandlung**

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Marcel Waldhof
aus Detmold**

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Preface

This thesis is the result of my time as a research associate at the Institute for Electrical Energy Conversion at the University of Stuttgart. On this point it is time to say

THANK YOU.

First of all, I would like to express a special thanks to my doctoral mother Nejila, who has always supported me and had my back. Her open-mindedness towards new ideas and her trust in my work made it possible for me to realize my ideas for this thesis.

Next, I would like to thank my second reviewer Syn as well as his team Isabell and Kathrin. The collaboration in the joint research project in the performance center „Mass Personalization“ had a big part in the results of this thesis.

Of course, a big thanks goes to my colleagues during my time at the institute, who always supported me with an open ear and clever advice. Especially I would like to thank Martin and Jonny, who got me through one or the other ups and downs of the daily institute work or technical hassles. Beside my colleagues, I am very grateful for all of my students, who helped me with their ideas and theses. Especially, I want to mention Philipp, Chris, Gernot, Benedikt and Alex.

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Stuttgart, April 2022

Marcel Waldhof

Abstract

Exoskeletons are powerful wearable robotic devices for people with medical impairments or for physically challenging tasks.

The dimensioning of the individual components, especially of the electric drive, is often conducted for maximum, worst-case scenarios, without considering the individuality of the user or the variety of tasks. The strong over dimensioning leads to a high unacceptance of the users.

An increase in acceptance by reducing the weight should be achieved by a personalized and scalable design of the exoskeleton drive.

A scalable human model allows the individual determination of the necessary forces of the drive unit. By systematically analyzing the load profile, frequently occurring operating points can be determined and used for machine calculations. The developed scaling model of the double-sided multi-phase axial flux machine leads to an optimal adaptation of the drive to the user. The developed, partially additive manufacturing process of the axial flux machine enables production in quantities of one.

Within the scope of this work, it is shown that the individual adaptation of the drive unit is necessary and feasible. This enables a weight saving of up to 20 % on the personalized electric machine.

Keywords: Robotics, Axial Flux Machine, Multi-Phase-Machines, Scalability, Additive Manufacturing

Zusammenfassung

Exoskelette sind leistungsfähige tragbare robotische Geräte für Menschen mit medizinischen Einschränkungen oder bei körperlich belastenden Aufgaben.

Die Dimensionierung der Einzelkomponenten, speziell des elektrischen Antriebs, wird oftmals für maximale, worst-case Szenarien durchgeführt, ohne die Individualität der Nutzer oder die Vielfalt der Aufgaben zu berücksichtigen. Die starke Überdimensionierung führen zu einer hohen Inakzeptanz der Nutzenden.

Eine Akzeptanzsteigerung durch die Reduzierung des Gewichtes soll mittels eines personalisiertem und skalierbarem Design des Exoskelett-Antriebs erreicht werden.

Ein skalierbares Menschmodell ermöglicht die individuelle Ermittlung der notwendigen Kräfte der Antriebseinheit. Durch die systematische Analyse des Lastprofils können häufig auftretende Betriebspunkte bestimmt und für die Maschinenberechnung genutzt werden. Das erarbeitete Skalierungsmodell der doppel-seitigen mehr-strängigen Axialflussmaschine führt zu einer optimalen Anpassung des Antriebs auf den Nutzenden. Das entwickelte, teilweise additive Herstellungsverfahren der Axialflussmaschine ermöglicht die Herstellung in Stückzahl eins.

Im Rahmen dieser Arbeit wird gezeigt, dass die individuelle Anpassung der Antriebseinheiten notwendig und realisierbar ist. Dies ermöglicht eine Gewichtsersparnis von bis zu 20 % an der personalisierten elektrischen Maschine.

Keywords: Robotik, Axialflussmaschine, Mehrsträngige elektrische Maschinen, Skalierbarkeit, Additive Herstellung

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