

# **Innovative Kleinantriebs- und Kleinmotorentechnik 2022 Beitrage der 13. GMM/ETG-Fachtagung (IKMT 2022)**

GMM-Fachbericht 103

Linz, Austria  
14 - 15 September 2022

ISBN: 978-1-7138-6303-8

**Printed from e-media with permission by:**

Curran Associates, Inc.  
57 Morehouse Lane  
Red Hook, NY 12571



**Some format issues inherent in the e-media version may also appear in this print version.**

Copyright© (2022) by VDE VERLAG GMBH  
All rights reserved.

Printed with permission by Curran Associates, Inc. (2023)

For permission requests, please contact VDE VERLAG GMBH  
at the address below.

VDE VERLAG GMBH  
Bismarckstr. 33  
P.O.B. 12 01 43  
10625 Berlin, Germany

Phone: +49 30 34 80 01 - 0  
Fax: +49 30 34 80 01 - 9088

[kundenservice@vde-verlag.de](mailto:kundenservice@vde-verlag.de)

**Additional copies of this publication are available from:**

Curran Associates, Inc.  
57 Morehouse Lane  
Red Hook, NY 12571 USA  
Phone: 845-758-0400  
Fax: 845-758-2634  
Email: [curran@proceedings.com](mailto:curran@proceedings.com)  
Web: [www.proceedings.com](http://www.proceedings.com)

## Inhaltsverzeichnis

### Permanentmagneterregte Synchronmotoren (Teil 1)

Sitzungsleiter: A. Mütze, Technische Universität Graz; B. Ponick, Leibniz Universität Hannover

- 1 Permanent Magnet Synchronous Motors with Three-zone Distributed Tooth-coil Winding ..... 11**  
M. Baun<sup>1</sup>, G. Huth<sup>2</sup>  
<sup>1</sup>ebm-papst Mulfingen GmbH & Co. KG, Germany; <sup>2</sup>University of Kaiserslautern, Germany
- 2 Influence of the Winding Variant on the Operating Behaviour of PM Synchronous Motors in the Field Weakening Range ..... 18**  
S. Mathis<sup>1</sup>, G. Huth<sup>2</sup>  
<sup>1</sup>ebm-papst Mulfingen GmbH & Co. KG, Germany; <sup>2</sup>University of Kaiserslautern, Germany
- 3 High Efficient and Cost-effective Solutions for Small Electric Motor Applications ..... 25**  
G. Dajaku, FEAAM GmbH, Neubiberg, Germany
- 4 Challenges and Design Aspects of Power Electronically Fed PCB Motor Windings ..... 32**  
A. Bauer, B. H. Zacher, Ch. Schumann, S. Urschel, Kaiserslautern University of Applied Sciences, Germany

### Antriebsregelung

Sitzungsleiter: A. Dietz, Technische Hochschule Nürnberg; C. Fräger, Hochschule Hannover

- 5 Reinforcement Learning-based Deep Q Direct Torque Control with Adaptable Switching Frequency Towards Six-step Operation for Permanent Magnet Synchronous Motors ..... 38**  
B. Haucke-Korber, M. Schenke, O. Wallscheid, Paderborn University, Germany
- 6 An Integrated Fast Resettable Integrator Circuit Based on Switched Capacitors for Sensorless Control of PMSMs ..... 44**  
N. König<sup>1</sup>, A. Stanitzki<sup>2</sup>, M. Nienhaus<sup>1</sup>, E. Grasso<sup>1</sup>  
<sup>1</sup>Saarland University, Saarbruecken, Germany;  
<sup>2</sup>Institute for Microelectronic Circuits (IMS), Duisburg, Germany
- 7 A Holistic, Highly Dynamic Drive Control Concept for an Elastic, Systems with Flawed or Incomplete Sensor Data ..... 50**  
Ch. Tkany<sup>1</sup>, M. Grotjahn<sup>1</sup>, J. Kühn<sup>2</sup>  
<sup>1</sup>University of Applied Sciences Hannover, Germany; <sup>2</sup>Lenze SE, Aerzen, Germany
- 8 On-Chip Simulation of a Nine-phase Electrical Drive and Power Electronics for Rapid Control Prototyping Applications ..... 57**  
V. Hoppe<sup>1</sup>, T. Schindler<sup>1</sup>, M. Hoerner<sup>1</sup>, A. Dietz<sup>1</sup>, R. Kennel<sup>2</sup>  
<sup>1</sup>Technische Hochschule Nuremberg, Germany; <sup>2</sup>Technical University of Munich, Germany

## Permanentmagneterregte Synchronmotoren (Teil 2)

Sitzungsleiter: A. Mütze, Technische Universität Graz; B. Ponick, Leibniz Universität Hannover

- 9 Application-optimal Design of a Permanent Magnet Synchronous Machine with Regard to Different Load Profiles ..... 63**  
 P. Schwarz, A. Möckel, Technische Universität Ilmenau, Germany
- 10 Noise and Vibration Characteristics of the Single-phase Claw-pole BLDC Machine with Different Stator Topologies ..... 69**  
 N. Saed<sup>1,2</sup>, S. Leitner<sup>1,2</sup>, A. Mütze<sup>1,2</sup>  
<sup>1</sup>Christian Doppler Laboratory for Brushless Drives for Pump and Fan Applications, Graz, Austria;  
<sup>2</sup>Graz University of Technology, Austria
- 11 Test Rig Evaluation of Different High-speed PMSM Stator Topologies ..... 74**  
 A. Pröll<sup>1</sup>, P. Dirnberger<sup>2</sup>, Ch. Dobler<sup>1</sup>, W. Gruber<sup>1</sup>  
<sup>1</sup>Johannes Kepler Universität Linz, Austria; <sup>2</sup>Linz Center of Mechatronics GmbH, Austria
- 12 Concept of PCB Motor for Fan Applications with Ferrite Core..... 81**  
 S. Asgari<sup>1,2</sup>, A. Muetze<sup>1,2</sup>  
<sup>1</sup>Christian Doppler Laboratory for Brushless Drives for Pump and Fan Applications, Graz, Austria;  
<sup>2</sup>Graz University of Technology, Austria

## Motoroptimierung

Sitzungsleiter: A. Dietz, Technische Hochschule Nürnberg; S. Silber, Linz Center of Mechatronics GmbH

- 13 Causal PMSM Model: Fast, Accurate, Robust ..... 85**  
 M. Hanke, H. Baumgartl, CADFEM Germany GmbH, Berlin, Germany
- 14 Tolerance Analysis and Robust Optimization for Electric Machine Design..... 90**  
 G. Bramerdorfer, E. Marth, Johannes Kepler Universität Linz, Austria
- 15 Optimization in the Loop..... 97**  
 Ph. Hugelmann<sup>1</sup>, J. Halfmann<sup>1</sup>, A. Roesch<sup>2</sup>  
<sup>1</sup>Robert Bosch GmbH, Bühl, Germany;  
<sup>2</sup>Schaeffler Automotive Buhl GmbH & Co. KG, Buhl, Germany
- 16 Optimised Large-scale Production of Plastic-bonded Magnetic Rotors for Small Motors ..... 103**  
 D. Schwegler, H. Schell, MS-Schramberg GmbH & Co. KG, Germany

## Asynchronmotoren und geschaltete Reluktanzmotoren

Sitzungsleiter: G. Bramerdorfer, Johannes Kepler Universität Linz;

S. Silber, Linz Center of Mechatronics GmbH

- 17 Automatic Commissioning of a Switching Frequency Based Sensorless Control Method for a Switched Reluctance Motor..... 110**  
 A. Walz-Lange<sup>1</sup>, G. Schullerus<sup>2</sup>  
<sup>1</sup>Robert Bosch GmbH, Reutlingen, Germany; <sup>2</sup>Reutlingen University, Germany
- 18 Optimization of the Current Operating State of Induction Machines Based on Electrical Quantities..... 116**  
 J. Moos, C. Fräger, Hochschule Hannover, Germany

- 19 Discharge Bearing Currents in Small Inverter-fed Induction Machines with Rated Power of 90 W..... 122**  
 M. Weicker, A. Binder, Technische Universität Darmstadt, Germany

### Linearantriebe

Sitzungsleiter: B. Gundelsweiler, Universität Stuttgart; J. Halfmann, Robert Bosch GmbH, Bühl

- 20 Integration of Inductive Energy Transfer into the Guidance of a Linear Direct Drive ..... 128**  
 M. Mittag, B. Gundelsweiler, University of Stuttgart, Germany
- 21 Completely Integrated Electromagnetic Dog Clutch Actuator for Automotive Applications..... 133**  
 F. Poltschak, D Rafetseder, Johannes Kepler Universität Linz, Austria
- 22 Analytical and Numerical Calculation of the Radial Force of a Reluctant Solenoid Linear Motor Using a Cross-sectional Area Invariant Geometry Transformation..... 139**  
 M. Voigtmann, R. Werner, Technische Universität Chemnitz, Germany

### Thermische Modellbildung

Sitzungsleiter: E. Marth, Johannes Kepler Universität Linz; B. Hagemann, Delta Electronics, Bruchsal

- 23 Influence of Secondary Insulation on the Possible Electrical Stress of a PMSM with Natural Air Cooling ..... 144**  
 T. Heidrich, A. Möckel, Technische Universität Ilmenau, Germany
- 24 Real-time AI-based Temperature Estimation of Small Electric Drives..... 149**  
 S. F. Sarcheshmeh<sup>1</sup>, S.-E. Asmussen<sup>2</sup>, N. König<sup>1</sup>, M. Nienhaus<sup>1</sup>  
<sup>1</sup>Saarland University, Germany;  
<sup>2</sup>SHARE am KIT, Schaeffler Technologies AG & Co. KG, Karlsruhe, Germany
- 25 Application of Thermal Neural Networks on a Small-scale Electric Motor ..... 155**  
 W. Kirchgässner<sup>1</sup>, D. Wöckinger<sup>2</sup>, O. Wallscheid<sup>1</sup>, G. Bramerdorfer<sup>2</sup>, Joachim Böcker<sup>1</sup>  
<sup>1</sup>Paderborn University, Germany; <sup>2</sup>Johannes Kepler University Linz, Austria
- 26 Advanced Data-based Temperature Modeling of an External Rotor PM Machine Considering an Optional Housing..... 161**  
 D. Wöckinger<sup>1</sup>, G. Bramerdorfer<sup>1</sup>, T. Krainer<sup>1</sup>, W. Amrhein<sup>1</sup>, R. Keller<sup>2</sup>, B. Mund<sup>2</sup>  
<sup>1</sup>Johannes Kepler University Linz, Austria;  
<sup>2</sup>Dr. Fritz Faulhaber GmbH & Co. KG, Schönaich, Germany

### Spezielle Aktuatoren

Sitzungsleiter: B. Gundelsweiler, Universität Stuttgart; P. Pott, Universität Stuttgart

- 27 Antagonistic Twisted String Actuation for Disposable Flexible Medical Robots ..... 168**  
 G. A. Giacoppo, A. L. Bachmann, P. P. Pott, University of Stuttgart, Germany
- 28 Twisted-String Actuator with Hollow Shaft for Portable Orthotic Devices ..... 173**  
 S. Weymann<sup>1</sup>, Ch. G. Pretty<sup>2</sup>, P. P. Pott<sup>1</sup>  
<sup>1</sup>University of Stuttgart, Germany  
<sup>2</sup>University of Canterbury, Christchurch, New Zealand

- 29 Analysis of Design Parameters' Influence on the Behavior of MSM-controlled PM-based Reluctance Actuators ..... 178**  
 M. Hutter, B. Gundelsweiler, University of Stuttgart, Germany
- 30 Design of a Hybrid Electromagnetic Switching/Holding Solenoid with Adjustable Core..... 184**  
 M. Mauch, B. Gundelsweiler, University of Stuttgart, Germany

### **Magnetlagertechnik**

Sitzungsleiter: W. Gruber, Johannes Kepler Universität Linz;  
 H. Mitterhofer, Linz Center of Mechatronics GmbH

- 31 The Bearingless Rotary-linear Reluctance Motor (BRLRM) – Position Measurement and Control in Six Degrees of Freedom..... 190**  
 A. Schleicher, R. Werner, Technische Universität Chemnitz, Germany
- 32 Design of a Bearingless Permanent Magnet Synchronous Machine for High Speed Applications..... 196**  
 M. Weigelt, F. Lorenz, A. Schleicher, R. Werner Technische Universität Chemnitz, Germany
- 33 Control of Magnetically Levitated Rotors with Defective Bearings or Sensors ..... 203**  
 M. Hutterer, Technische Universität Wien, Austria
- 34 Indirect Efficiency Measurement and Levitation Property Determination for High-speed Bearingless PM Synchronous Machines..... 209**  
 D. Dietz, A. Binder, Technical University of Darmstadt, Germany

### **Materialcharakterisierung und -verluste**

Sitzungsleiter: W. Amrhein, Johannes Kepler Universität Linz; J. Halfmann, Robert Bosch GmbH, Bühl

- 35 Precise, Fast and Easy Method for Iron Losses Calculation in Non-slotted, Small Electric Motors with Air Gap Winding..... 216**  
 B. Mund, Dr. Fritz Faulhaber GmbH & Co. KG, Schönaich, Germany
- 36 Reduction of Eddy Current Losses in Stacked Laminations via Electrochemical Deburring ..... 222**  
 N. Trnka, A. Schleicher, F. Lorenz, R. Werner, Technische Universität Chemnitz, Germany
- 37 Investigations on Methods for Determination of Soft Magnetic Material Properties for a Novel Measurement Setup for Evaluating the Effect of Mechanical Stress..... 228**  
 G. Goldbeck, G. Bramerdorfer, D. Wöckinger, Ch. Dobler, W. Amrhein, Johannes Kepler Universität Linz, Austria; Bernhard Weiß, voestalpine Stahl GmbH, Linz, Austria
- 38 Soft Magnetic Material Characterisation with a Single Sheet Tester – An Overview..... 234**  
 Ch. Dobler, D. Wöckinger, G. Goldbeck, G. Bramerdorfer, W. Amrhein, Johannes Kepler Universität Linz, Austria

## Motorkomponenten

Sitzungsleiter: K. H. Dempewolf, Wittenstein GmbH, Igersheim;  
G. Bramerdorfer, Johannes Kepler Universität Linz

- 39 Multi Parameter Analysis of Layer Insulation of Segmented Magnets..... 239**  
M. Königs<sup>1</sup>, B. Löhlein<sup>1</sup>, J. Prossel<sup>2</sup>  
<sup>1</sup>University of Applied Sciences Flensburg, Germany; <sup>2</sup>Engineering, Bomatec AG, Hori, Switzerland
- 40 Do Fast-switching Inverters Endanger the Motor Insulation System? Laboratory Tests..... 246**  
V. Grabs, Lenze SE, Aerzen, Germany
- 41 Innovative Rectangular Magnet Wires for Use in Powertrain Applications ..... 251**  
J. Reicher, R. Haase, A. Levermann, Schwering und Hasse Elektrodraht GmbH, Lügde, Germany

## Condition Monitoring

Sitzungsleiter: E. Marth, Johannes Kepler Universität Linz; P. Pott, Universität Stuttgart

- 42 A Wireless and Batteryless Online Condition Monitoring System for Rolling Bearing Heat Damage Avoidance ..... 255**  
F. Hammer<sup>1</sup>, L. B. Hörmann<sup>1</sup>, M. Scherhäufel<sup>1</sup>, G. Kaineder<sup>1</sup>, K. Grissenberger<sup>2</sup>  
<sup>1</sup>Linz Center of Mechatronics GmbH, Austria; <sup>2</sup>NKE Austria GmbH, Steyr, Austria
- 43 Simulation-assisted Training of Neural Networks for Condition Monitoring of Electrical Drives: Approach and Proof of Concept..... 260**  
E. Marth<sup>1</sup>, P. Zorn<sup>1</sup>, F. Schmid<sup>1,2</sup>, S. Masoudian<sup>2</sup>, K. Koutini<sup>2</sup>, W. Amrhein<sup>1</sup>  
<sup>1</sup>Johannes Kepler University Linz, Austria; <sup>2</sup>LIT AI Lab, Linz Institute of Technology (LIT), Austria
- 44 Simulation-assisted Training of Neural Networks for Condition Monitoring of Electrical Drives: Enhanced Domain Adaptation Methods..... 267**  
F. Schmid<sup>1,2</sup>, S. Masoudian<sup>2</sup>, E. Marth<sup>1</sup>, P. Zorn<sup>1</sup>, K. Koutini<sup>2</sup>, G. Widmer<sup>1,2</sup>  
<sup>1</sup>Johannes Kepler University Linz, Austria;  
<sup>2</sup>LIT AI Lab, Linz Institute of Technology (LIT), Austria

## Postersession

Sitzungsleiter: Carsten Fräger, Hochschule Hannover; Hubert Mitterhofer, Linz Center of Mechatronics GmbH

### P.1 Permanentmagneterregte Synchronmaschinen

- 45 Development of a Novel Brushless DC Motor for Fuel Pumps without Dynamic Seal Shafts for Increased Reliability..... 274**  
J. Ott<sup>1</sup>, R. Mazuheli<sup>1</sup>, M. Gschwandl<sup>1</sup>, H. Häusel<sup>2</sup>  
<sup>1</sup>Ottronic Regeltechnik Gesellschaft m.b.H., Fohnsdorf, Austria;  
<sup>2</sup>HP-Tech GmbH, Maria Buch, Austria
- 46 Design of High Efficient PM Synchronous Motor in Ferrite Technique with Special Regard to Manufacturing Aspects and Application Flexibility..... 278**  
J. Frevert, Hanning Elektro-Werke GmbH & Co. KG, Oerlinghausen, Germany
- 47 A Fast Simulation Method for Drives with Ironless Stators**  
K. Radman<sup>1</sup>, W. Gruber<sup>2</sup>, H. Mitterhofer<sup>1</sup>  
<sup>1</sup>Linz Center of Mechatronics GmbH, Austria; <sup>2</sup>Johannes Kepler Universität Linz, Austria

## P.2 Antriebsregelung

- 48 **Faster Time to Market with New Motor Control Algorithms using Rapid Prototyping Tools**  
C. Baumgartner, Microchip Technology Austria GmbH

## P.3 Magnetlagertechnik

- 49 **Optimization of Axial Magnetic Bearing for Application of Vibration Assisted Drilling ..... 283**  
G. Messenger, G. Che, H. Kasten, Ch. Redemann, KEBA Industrial Automation Germany GmbH,  
Lahnau, Germany
- 50 **Evaluation of a Bearingless Magnetic Geared Motor Prototype**  
W. Gruber, T. König, Johannes Kepler Universität Linz, Austria
- 51 **Functional Design Analysis of Bearingless Magnetically Geared Motors with Combined Windings**  
W. Gruber, T. Strinic, Johannes Kepler Universität Linz, Austria
- 52 **Design of a Dynamic KALMAN-Filter for a Stray Flux Based Measurement System of Magnetic Bearings ..... 289**  
J. Rudolph, R. Werner, Technische Universität Chemnitz, Germany

## P.4 Spezielle Aktuatoren

- 53 **Endurance Test Rig for Twisted String Actuators ..... 295**  
G. A. Giacoppo, M. B. Schäfer, P. P. Pott, University of Stuttgart, Germany
- 54 **Design of a Linear Magneto-mechanical Bio-actuator for Cell-alignment in Tissue Engineering ..... 299**  
W. Zhang<sup>1,2</sup>, L. Decker<sup>1</sup>, A. Christmann<sup>1</sup>, J. Panzer<sup>1</sup>, S. Urschel<sup>1</sup>, B. Gundelsweiler<sup>2</sup>  
<sup>1</sup>University of Applied Science Kaiserslautern, Germany; <sup>2</sup>University of Stuttgart, Germany

## P.5 Motoroptimierung

- 55 **Non-parametric Optimization for Electrical Machines**  
S. Reitzinger, Dassault Systèmes Austria GmbH
- 56 **Efficient Frequency-domain Evaluation of Transient Voltage Effects in Electric Machines**  
B. Wex<sup>1</sup>, S. Silber<sup>1</sup>, W. Gruber<sup>2</sup>  
<sup>1</sup>Linz Center of Mechatronics GmbH, Austria; <sup>2</sup>Johannes Kepler University Linz, Austria

## P.6 Motorkomponenten

- 57 **Electrical Insulating Resins – Requirements and Processing**  
M. Brodbeck, ELANTAS Europe GmbH, Hamburg, Germany

## P.7 Condition Monitoring

- 58 **Property Characterization of an Integrated Torque Sensing Device for Gearboxes ..... 307**  
F. Schwenker, Dr. Fritz Faulhaber GmbH & Co. KG, Schönaich, Germany