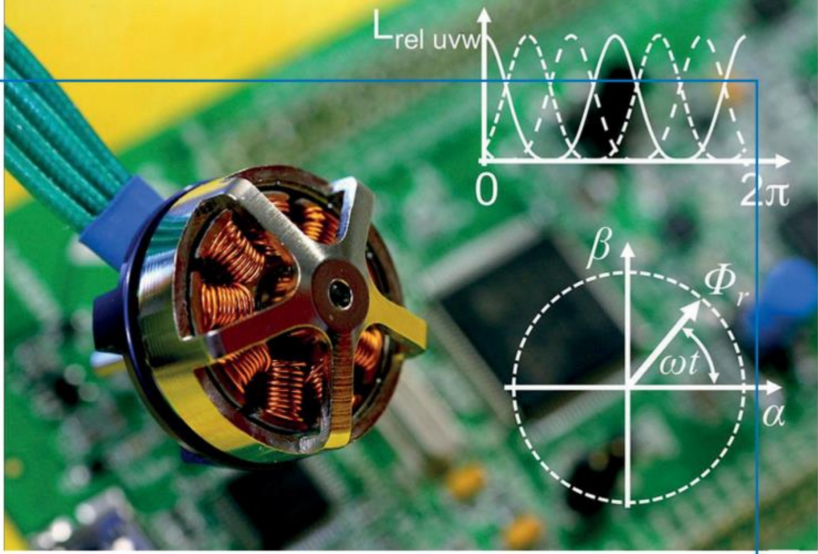
Programm

12. ETG/GMM-Fachtagung



IKMT 2019

Innovative Klein- und Mikroantriebstechnik
Innovative small drives and micro-motor systems

10. - 11. September 2019, Würzburg, Burkardushaus

VDE VDI GMM VDE ETG

Uhr	Dienstag, 10.09.	Uhr	Mittwoch, 11.09.
09:30	Begrüßung	08:30	Begrüßung
09:40	Keynote (1)	08:40	Keynote (3)
10:10	**Direktantriebe**	09:10	**Entwurf und Simulation 2**
11:10	Kaffeepause + Table Top Ausstellung	10:30	Kaffeepause + Table Top Ausstellung
11:40	**Entwurf und Simulation 1**	11:00	**Antriebssteuerung und Antriebsregelung**
13:00	Mittagsimbiss	12:20	Mittagsimbiss
14:30	Keynote (2)	13:20	Antriebssteuerung und Antriebsregelung (Forts.)
15:00	**Piezoelektrische und unkonventionelle Antriebe**	14:00	**Mechatronische Antriebssysteme 2**
16:10	Kaffeepause + Table Top Ausstellung	14:40	Verleihung Best Paper Award
16:50	**Mechatronische Antriebssysteme 1**	14:50	Schlusswort
19:00	Abendveranstaltung	15:00	Ende der Veranstaltung

Titelbild: Matthias Nienhaus, Universität des Saarlandes

Keynotes

Weiterentwicklung der SE-Magnetwerkstoffe für die elektrische Antriebstechnik (Keynote)

Christoph Brombacher, Vacuumschmelze GmbH & Co. KG, Hanau, Deutschland

(2) Trends bei medizintechnischen Antriebssystemen (Keynote)

Thomas Roschke, Johnson Medtech LLC, Vandalia, USA

(3) Hochauflösende miniaturisierte Längenmesssysteme auf magnetischer Basis für Klein- und Mikroantriebe (Keynote)

Rolf Slatter, Sensitec GmbH, Lahnau, Deutschland

Es gibt einen wachsenden Bedarf an miniaturisierten Längenmesssystemen. Systeme auf magnetischer Basis sind im Vergleich zu optischen Messsystemen äußerst robust und günstig, erreichen aber nicht deren Genauigkeit. Im Verbundprojekt Aquila werden neue Sensoren und lithographisch hergestellte Maßstäbe entwickelt, um den Genauigkeitsabstand zu den optischen Gebern zu eliminieren, bei deutlich kleineren Abmessungen. Ein Demonstrator mit einer Messlänge von 25 mm erreicht eine absolute Positioniergenauigkeit von kleiner 700 nm und eine bidirektionale Wiederholgenauigkeit kleiner gleich 110 nm. Er arbeitet absolut und benötigt somit beim Einschalten keine Referenzfahrt mehr. Die Leistungseigenschaften dieser neuen Lösung werden in ersten Pilotanwendungen erprobt.

Direktantriebe

Linear Direct Drive with Inductive Energy Transmission

Marcel Mittag, Bernd Gundelsweiler, University of Stuttgart, Germany

Linear direct drives, which based on the electrodynamic operating principle, are designed with a moving coil or magnet system. The advantage of such a system with moving magnets is the unnecessity for current supply at the armature, while its disadvantage lies in the increased material and control effort caused by the coils in the stator. Those drives with a moving coil system have higher dynamics due to a lower moving mass, but in turn require the power supply to be carried along. Trailing cables, which also carry the cable for data transmission, are used for longer travel ranges. As an additional disturbance due to its length and weight, the trailing cable is a mechanical component, which limits the dynamics and positioning accuracy. It also increases the sensitivity to cable breakage. A moving coil system with inductive energy transmission makes the trailing cables superfluous and benefits from the higher dynamics as well as from the prevention of cable breakage. This paper presents a concept that enables a linear direct drive to be powered wirelessly. The energy transfer takes place inductively according to the transformer principle. As a coaxial transformer, an inductive coupling is established between a stationary primary coil and a moving secondary coil via a toroidal ferrite. This allows the armature with toroidal core and secondary coil without mechanical contact. The control and power electronics

are mounted entirely on the armature. Creating a linear direct drive with a moving coil system, that can be operated without a trailing cable and with position control.

Design of an Integrated Linear Flux Modulating Motor for a Direct-drive Belt Conveyor

Alexander Hoffmann, Malte Kanus, Ludger Overmeyer, Bernd Ponick, Leibniz University Hannover, Germany

This article covers the novel design of a linear hybrid flux modulating motor for direct-driven belt conveyors and gives insight into considerations for manufacturing and system efficiency. In common approaches, belt conveyors are driven by attaching a geared electric machine to one of the drums, using the traction force between the drum and the belt to introduce linear motion. Since the contact area between the belt and the drum is small compared to the total belt surface, the achievable force in contact with the drum is limited. In order to increase the traction force between drum and belt, the tension inside the belt must be increased. The downside is higher mechanical stress and more complex belt designs to withstand the additional force. To overcome the mentioned aspects of common belt conveyors and to lead the way for new material flow models, a novel highly integrated and direct-driven belt conveyor is presented. Furthermore, the designed linear hybrid motor is presented in great detail: Analytical equations are given to determine the motor dimensions for a given moving force. Efficient 3D FEM simulation results are presented, utilizing the symmetric properties of the motor to reduce simulation time considerably. The results are ranging from magnetic flux density distribution to the working point of the permanent magnet.

Resource-saving circulation pump through optimization of the integrated canned motor

Juri Dolgirev, Marc Kalter, Sven Urschel, University of Applied Sciences Kaiserslautern, Germany; Ralph Funck, Jens Jung, Volker Schimmelpfennig, CirComp GmbH, Kaiserslautern, Germany

A circulation pump is an integrated unit, consisting of a hydraulic part for transmitting energy to the medium and a driving canned electric motor. The strict efficiency standards for circulation pumps set by the European Union led to the fact, that today synchronous motor with cost-intensive and resource critical rare earth magnets are state of the art. This paper presents a new resource saving design for canned motors of circulation pumps based on a novel separation can in combination with a ferrite assisted synchronous reluctance motor.

Entwurf und Simulation 1

Comparison of PM line-start motors with surface-mounted and inserted magnets

Gerhard Huth, Hans-Georg Schirmer, University of Kaiserslautern, Germany

Improving the energy efficiency of AC line-start drives is the declared development goal of today. Due to the limiting physics of cage induction motors employed so far, motors with small frame size have difficulties to reach the high power density required to achieve efficiency class IE4. The solution are PM line-start motors instead of energy-inefficient cage induction motors. Commonly, PM line-start motors are manufactured with permanent magnets inserted in the laminated

rotor core. An alternative rotor design enables the arrangement of permanent magnets directly on the rotor surface. Apart from describing their development and design, this study compares the two rotor variants, using the example of frame size AH 90, by contrasting simulation with measurement results. Both rotor designs have specific effects on the start-up and pull-in behavior as well as on the steady-state behavior in synchronism.

PM line-start short motors with double tooth-coil winding

Gerhard Huth, University of Kaiserslautern, Germany; Jens Krotsch, ebm-papst Mulfingen GmbH & Co. KG, Mulfingen, Germany

In fan and pump drives, 2- and 4-pole AC line-start motors are preferred in the lower power range. Premium efficiency classes are achievable in this power range with PM line-start motors. The latter ones are designed with a three-phase stator that is manufactured with a distributed integer-slot winding. Particularly unfavorable is a core length which is a lot shorter than the stator diameter. In such short motors, 70 - 90 % of the winding copper is inactive in the end-winding region, which has a large negative effect on the motor performance. This kind of 2- and 4-pole short motors would require winding systems with considerably shorter end windings. Distributed tooth-coil windings are one possible solution. In this paper, the principle of a distributed tooth-coil winding will be described using the example of a double tooth-coil winding. Based on a simulation study, we will outline the effect of different three-phase windings on the steady-state performance as well as on the starting and pull-in behavior.

Influence of inverter harmonics on continuous performance of a permanent magnet drive

Sven Luthardt, Rödental, Germany; Dieter Gerling, Bundeswehr University Munich, Neubiberg, Germany

Modern electric motors are often controlled by inverter topologies. Challenging package and weight requirements in all industrial sectors lead to a high power density of the electric drive system in all components. Therefore, dependencies between the different components can create parasitic effects, which were neglected in the past. One of these effects is the influence of the inverter harmonics on the performance of an electric motor. This paper deals with a study of the losses and continuous performance of a high power density permanent magnet motor fed by a two-level voltage source inverter.

Electric machine design automation with Python and ANSYS Maxwell

Patrick Schwarz, Andreas Möckel, Technical University Ilmenau, Germany

Nowadays global competition is characterized by high innovation speed as well as short development and product life cycles. Especially the field of electric machines is marked by rising expectations regarding efficiency, power density and production costs. In order to keep development times as low as possible and realize optimization loops in workable periods, effective design approaches are necessary. Usually the preliminary design is based on an experience-based approach with analytical equations. In further steps the design is often verified by static or transient finite element method (FEM) and optimized in details by parameter variations within an experience-based parameter area. In general, there are several strategies for optimizing machine designs, starting with analytical calculations over finite element method

calculations up to self-learning systems. The work on this paper is based on the idea of defining experience-based and productspecific sequences of steps with appropriate weighting and adapted parameter areas. Furthermore, these sequences will be processed automatically. An automated FEM-model generation is essential for this kind of optimization. This paper is focused on the model generation based on the open source programming language Python and the commercial simulation program ANSYS Maxwell.

Piezoelektrische Antriebe, unkonventionelle Antriebe

Piezo-Actuated XYPhi-Motor based on Hemispherical Resonators

Frank Schiele, Bernd Gundelsweiler, Wolfgang Schinköthe, University of Stuttgart, Germany

Ultrasonic piezo motors are used in precision positioning systems, especially when a magnetic field-free drive solution is required. Their strength also lies in zero energy consumption at stand still. The operating principle is based on resonant vibration of a piezo resonator and results in elliptical or linear, inclined trajectories moving a friction contact. Usually, these piezo motors are guided in a linear direction. In order to achieve a XYPhi-stage, a perpendicular setup of two linear drives combined with a rotational stage is typically required. This sandwich-like stacked setup leads to disadvantages, like large installation spaces and unnecessarily moved masses. To create movements in X-Y- and f-direction on a single level platform, a setup is presented that uses three piezo resonators, each generating a three-dimensional trajectory. The all-ceramic, hemispherical vault piezo resonators used [1] prove to be a suitable alternative to composite resonators due to low manufacturing and assembly costs. A controller setup to control the direction of the motor is shown.

Magnetic Flux Control through Magnetic Shape Memory Alloys in Reluctance Actuators

Marco Hutter, Markus Raab, Bernd Gundelsweiler, University of Stuttgart, Germany; Arif Kazi, Fabian Wolf, Aalen University of Applied Sciences, Germany

High-performance mechatronics which can be used in clean rooms – e.g. magnetically levitated systems – requires innovative actuator concepts. Actuators should have high power density, low energy consumption during stationary operation, very low wear and abrasion, and contactless force generation. Magnetic shape memory alloys (MSM) actuators offer a high strain of up to 6 % as well as multi-stable positioning and therefore have low power dissipation under static load. The strain of an MSM stick determines its permeability, which can be used as a sensory effect. Present MSM actuator concepts, however, do not offer contactless force generation. This paper shows the concept, key experiments and simulations of an MSM stick as variable magnetic reluctance in a permanent magnetic reluctance actuator. The adjustable reluctance of the MSM stick is used to control the magnetic flux and thus the force on a ferromagnetic armature. This approach promises compact, low-power and wear-free actuator designs, which can be combined with classic reluctance actuators.

Series and parallel actuation array of elastic micro-twisted string actuators

Savio A. D Souza, Pia Mühlbauer, Swantje Janzen, Jan Liu, Peter P. Pott, Universität Stuttgart, Germany

human-machine interaction. This comprises of not only the use in orthotic and prosthetic systems for lower extremities, arms, and wrists but also exo-skeletons. A TSA consists of a bundle of at least two fiber components and an actuator to twist it along its main axis. This forms a helical structure, which shortens the axial length – given non-elastic behaviour of the material. In practice, an axial bearing compensates for the load force and a linear guide counters the motor torque. In cases where a bi-directional force is required, a passive spring return mechanism can be included. Our work focuses on the integration of the described TSA components into a single elastic tube. Three TSAs are arranged in series and six in parallel such that they form an array that can bend in three dimensions with muscle-like behaviour and elastic properties. By switching motor units on and off, the length and force of the array can be varied between zero and maximum force without the need of an internal feedback loop. A first experiment is carried out to validate the force control. A possible application of this technology is soft medical robots for diagnostic and therapeutic purposes. The first demonstrator consists of three motor units in series. Six of these serial arrangements are combined in parallel forming an array of 18 motors. Each TSA unit consists of a DC motor, a string coupling including the axial bearing, the string made of high-density polyethylene, a cylindrical housing that protects the motor against axial forces, houses the DC motor, and provides the support for the previous unit. The entire TSA unit is encapsulated inside a thermoplastic polyurethane (TPU) tube which takes over the counter-torque, acts as linear bearing, is the return spring, and provides the elastic base for the TSA array. Thus, by using these modular units an infinite chain of TSA can be built and arranged as desired. The TSA units can be current-controlled and independently activated. Experiments showed that a no-load stroke of 18 mm and a maximum pulling force of 11 N can be achieved by a single TSA module. The spatial arrangement of the tubes allows muscle-like use in larger and anthropomorphic systems and also 2-dimensional bending and torsion of the array for soft robotic systems. Further work will comprise the improvement of the module, their miniaturization, simplified axial bearings, and integrated control electronics.

Demonstrator of a low-cost active knee orthosis with twisted string actuation

Pia Mühlbauer, Swantje Janzen, Kent Stewart, Peter P. Pott, University Stuttgart, Germany

This paper presents a demonstrative active knee orthosis to support sit-to-stand (STS) transfer movement, which is silent, simply constructed, small, lightweight, and low-cost. The demonstrative active knee orthosis is driven with a twisted string actuator (TSA) fixed to the lateral side of the upper rail. The TSA consists of two polyethylene strands which are twisted along its main axis by a DC motor. Linear guidance rails are used to counteract the motor torque on the load side of the TSA. The resulting helix structure formed in the twisted strings leads to a tensile force along the length of the TSA. At the knee joint, a cam disc converts this force into the desired support moment. Low-cost parts and materials were used when putting the demonstrator together to ensure the overall costs were kept to a minimum. An Arduino microcontroller and a H-bridge circuit provide the motor control, with a user controlled potentiometer specifying the desired speed. The demonstrator is 3D-printed via fused deposition modelling, with scaled down dimensions (scaling factor 0.7) compared to a normal knee orthosis. The costs, size, and noise of the demonstrator are kept low via the use of a simple TSA, replacing the need for heavy and noisy mechanical gear. Due to the simplicity of the system, the total costs are low (106 €), and thus are also expected to be low when creating a full scale version. The demonstrator shows a successful implementation of a TSA driven knee orthosis able to achieve STS-movement while being silent, lightweight and low-cost. Future work will look into improvements of the cam disc’s geometry and motor selection to achieve the desired knee torque profile in relation to the transfer movement. In addition, a full-scale version of the TSA knee orthosis will be constructed.

Mechatronische Antriebssysteme 1

Cooling of Linear Direct Drives in Precision Engineering with Piezo Fans

Simon Strohmeyr, Bernd Gundelsweiler, Wolfgang Schinköthe, Sabri Baazouzi, University of Stuttgart, Germany

Linear direct drives are used when high position accuracy and high dynamics in linear movements are required. During operation, drives can develop high temperatures which limit their performance. Especially drives with a moving coil have a poor thermal connection to the drive. This makes it difficult to transfer the heat caused by ohmic losses in the coil. In order to increase the power of the drive, an additional cooling system is required. The most commonly used systems are radial or axial fans, which increase the convection coefficients on the surface that needs to be cooled. These fans usually consist of a small DC motor, a bearing system and a fan impeller. These mechanical components, in particular, have an enormous effect on miniaturization, since the influence of friction increases with the downsizing of the system. This affects the efficiency and reliability of the cooling system. In frictionless systems, such as the piezoelectric fan [1] or the piezoelectric Dual Cooling Jet [2], an air flow is generated via the piezoelectric excitation of a cantilever beam or a membrane at resonant frequency. These cooling systems therefore show high potential for the efficient and reliable cooling of linear drives in precision engineering.

Influence of PM-Material on the Parameter Uncertainty of Bearingless Synchronous Machines

Daniel Dietz, Andreas Binder, Technical University of Darmstadt, Germany

Bearingless machines require an asynchronously rotating stator field wave in order to generate a non-moving force vector which is needed to control the position of the rotor. Such machines are oftentimes built with a solid permanent magnet ring on the rotor surface. Depending on the corresponding frequency and the electrical conductivity, the occurring eddy currents can lead to severe deformation of the exciting stator field wave. This causes a decrease in the force amplitude. Additionally, an error angle occurs between the reference and the actual bearing force vector. PM-materials with sufficiently high electrical conductivity, such as SmCo5, lead to these effects and may endanger robust control.

Entwurf und Simulation 2

Impact of different cutting methods on core losses and magnetizing demand of electrical steel sheets

Michael Reinlein, Dr. Ing. h.c. F. Porsche AG, Weissach, Germany; Martin Regnet, A. Kremser, Technische Hochschule Nürnberg, Germany; P. Szary, thyssenkrupp Steel Europe AG, Bochum, Germany; U. Abele, Gebrüder Waasner, Forchheim, Germany

In this paper, the influence of cutting edges on the core losses and magnetizing demand is illustrated. First, measurements are done of the magnetic properties of electrical steel test strips with different widths in the Single Sheet Tester (SST). The cutting techniques water jet cutting (WC) and wire eroding (WE) are investigated in order to receive reference measurement results. Guillotine shearing (GS) is considered because it is the standard method to produce test strips for the SST at the electrical steel sheet producers. Laser cutting (LC) is examined in face of prototyping of electrical machines. The focus of the measurements are test strips stamped with an industrial cutting tool (IC). The results from the measurements are integrated in an analytical and numerical electromagnetic model in [1]. The results of this paper are a part of [2].

Semi-analytical and numerical calculation of a great number of induc-tion machines taking into account cutting edges

Michael Reinlein, Dr. Ing. h.c. F. Porsche AG, Weissach, Germany; M. Regnet, A. Kremser, Technische Hochschule Nürnberg, Germany; P. Szary, thyssenkrupp Steel Europe AG, Bochum, Germany; U. Abele, Gebrüder Waasner, Forchheim, Germany

In this paper, the influence of cutting edges on the core losses and magnetizing current in induction machines is illustrated. An investigation of the influence of different cutting methods on the core losses and magnetization demand is presented in [1]. The results from the measurements are integrated in an analytical and numerical electromagnetic model. Three induction machines are numerically simulated to compare the results of the numeric and semi-analytic calculations. The semi-analytical calculation procedure is transferred on 850 induction machines (IM). The analytically calculated core losses and magnetizing current are compared with no load measurements. The results of this paper is a part of [2].

Numerical and Analytical Investigation of Rotor Eddy Current Losses for a Super High Speed Permanent Magnet Synchronous Motor

Jiawei He, Bernd Löhlein, Gerhard Huth, Technical University of Kaiserslautern, Germany

In diesem Beitrag wird zunächst ein Käfig-Modell zur Abschätzung der Rotorwirbelstromverluste vorgestellt. Das Modell basiert auf der Idee, die massive Hohlwelle in einzelne Stäbe zu unterteilen, da die Hohlwelle aus Hartmetall in dem Fall als Schirmung fungiert und somit die meisten Rotorwirbelstromverluste in der Hohlwelle induziert werden. Auf Grundlage der Luftspaltinduktion kann der fiktive Maschenstrom in jedem Stab des Käfig-Modells bestimmt werden, wodurch die gesamten Wirbelstromverluste in der Hohlwelle berechnet werden können. Zum Schluss werden die Ergebnisse des analytischen Berechnungsmodells mit FEM-Simulation verglichen. Der Vergleich zeigt, dass die vorgestellte analytische Abschätzung der Rotorwirbelstromverluste für hochtourige PM-Synchronmotoren mit dem betrachteten Läuferaufbau gut geeignet ist.

Concept of a two-stator axial flux machine with field-wound fiber-composite rotor

Fabian Endert, Andreas Möckel, Technical Universität of Ilmenau, Germany

The constant progress in calculation methods, materials and production technologies offers a new opportunity for alternative machine concepts. Axial flux machines are under investigation in current research projects because they can achieve high torque densities with a short installation length. By using composite materials in the magnetic circuit and in structural components, high-performance motors can be dimensioned on the basis of this concept. The interdisciplinary research group NEMOFASER is dedicated to the design of a double-stator axial flux machine with field-wound fiber composite rotor. The aim is to create a methodology for the competitive design of such a machine. Based on current axial flux configurations, the paper presents the preferred motor concept. By using an analytical approach, a preliminary dimensioning of the magnetic circuit is carried out. Finally, a prototype is highlighted, which was realized for model validation.

Antriebssteuerung und Antriebsregelung

Dual loop position control for mechanical systems with backlash and elasticity

Federico Percacci, Marko Tanaskovic, Weisheng Kong, Chen Zhao, Patrik Gnos, maxon motor ag, Sachseln, Switzerland

A dual loop position control architecture for electrical drives is presented. The architecture is designed for mechanical systems with backlash and elasticity between motor and load. It consists of a cascaded control structure where an inner feedback loop controls the motor speed, which is in turn nested in an outer feedback loop controlling the load position. The architecture is augmented with a notch filter to fight resonances and a gain scheduler to prevent chattering due to backlash. The control architecture is presented and the identification experiment and the auto-tuning procedure for the outer feedback loop are described.
The control architecture is tested on two mechanical systems, one with large backlash, the other with an underdamped resonance. Its performance is compared to that of a single loop position controller.

Comparison of Reinforcement Learning Algorithms for Speed Ripple Reduction of Permanent Magnet Synchronous Motor

Tobias Schindler, Lukas Fossa, Armin Dietz, Technische Hochschule Nürnberg, Nuremberg, Germany

In this paper, a reinforcement learning based approach for reducing the speed ripple of a permanent magnet synchronous motor is presented. The method assumes that the speed ripple is caused by a sinusoidal disturbance with known frequency. A test bench with a mechanical load, which causes such a sinusoidal disturbance due to a static unbalance, is used to evaluate the method. Different reinforcement learning algorithms (Q-learning, double Q-learning, SARSA) are compared by the means of simulation. The simulation results are verified on the test bench and experimental results are presented. It is shown that it is possible to learn a feed forward compensation method by RL agents. However, the performance of the method has a high dependency on the random seeds in all three investigated RL algorithms and does not learn this result reliably. Further investigations are necessary to determine the cause and possible mitigations of this lack of robustness of the implemented algorithms to enable industrial applications of reinforcement learning.

Comparison between sliding mode load-torque observer techniques for DC motor without torque sensor

Stefano Fabbri, Niklas König, Matthias Nienhaus, Emanuele Grasso, Saarland University, Saarbrücken, Germany

External load-torque estimation for electrical motor is important in order to improve the performance of the control and to have a better overview of the system state. In this paper, the external load torque applied upon the shaft of a DC motor is estimated by means of three different typologies of SMO (Sliding Mode Observer), namely, a first order sliding mode, a quasi-sliding mode and a super-twisting sliding mode observer. The observers are based on the position and speed measurement of the rotor without the need for a torque sensor. The estimation algorithm is implemented on an Embedded System with a DC motor. In this work, the performance as well as the computational effort and the robustness of these observers are compared experimentally.

Combination of two different sensorless techniques for complete speed range sensorless drive and control of small sized PMSMs

Stefano Fabbri, Klaus Schuhmacher, Matthias Nienhaus, Emanuele Grasso, Saarland University, Saarbrücken, Germany

A combination of two different sensorless techniques for small sized PMSMs are presented in this paper, namely, an alternate HFCI (High Frequency Current Injection) and a BEMF (Back Electro-Motive Force) based sensorless technique. The combination of the techniques is performed by means of two different switching functions. Through these functions the algorithm performs a complete speed-range sensorless drive and control of the electric motor including the standstill status. The switching algorithms use both the estimated angular speed and the estimated BEMF of the motor in order to perform the switching between the two sensorless techniques. The results in term of performance and reliability of the realized sensorless algorithms are presented within this work.

Hybrid amplitude and vibration control for a small-scale linear drive with two sliders magnetically spring-loaded

Abd Elkarim Masoud, Jürgen Maas, Technical University Berlin, Germany

This paper proposes an amplitude and vibration control for a small electric linear actuator consisting of two independently controllable sliders operated in resonance. Therefore, the sliders are axially spring-loaded by permanent magnets designed to match an operation frequency of about 50 Hz. One slider provides an adjustable oscillation amplitude, while the second one is utilized to reduce axial vibrations of the common housing and noise strongly induced by the first one. The overall systems result in a three-mass oscillator taking into account the movement of the common housing. To control the amplitude and vibration the derived model is transformed into an averaged model using the fundamental Fourier components. Based on this model a multivariable controller is designed taking into account the two different objectives for the amplitude and vibration control. Beside the design of the developed small electrical linear drive, the paper offers modelling aspects and the design as well as the experimental validation of the control.

Brushless Excitation System for Synchronous Machines with Rotary Transformer supplied by Common Mode Voltage

Stefan Udema, Carsten Fräger, University of Applied Sience and Arts, Hannover, Germany

This paper presents a brushless excitation system for inverter operated electrical excited synchronous machines without the necessity of an additional inverter for the excitation system. In order to fulfill the requirement of a brushless system, a rotary transformer transfers the power to the rotor field winding inductively. A rectifier connected to the rotating secondary winding of the transformer provides a DC-voltage to the rotor winding. The neutral conductor runs from the star point of the three stator phases trough the stationary primary winding of the rotating transformer and back to the center point between the intermediate circuit capacitors. A common mode voltage (CMV) with fixed frequency and variable amplitude is added to the 3-phase modulation for the inverter working with pulse width modulation (PWM). Since the star point is connected, a current driven by the CMV will flow in the neutral conductor. Through the amplitude of the CMV the voltage supplying the primary winding of the transformer can be regulated, which has a direct impact on the DC-voltage of the field winding i.e. the rotor excitation.

Aspects of High Performance Flat External Rotor Motors

Frank Schwenker, Dr. Fritz Faulhaber GmbH & Co. KG, Schönaich, Germany

Flat shaped motors have advantages, in comparison to rod shaped motors, when they are integrated into the limited installation- space in a wide range of applications. In this case motors with windings on iron cores in a slotted stator design are beneficial. The challenge is to design the drives as compact as possible: preserving as much of the feature from bell type armature motors with low cogging torque, and preserving as much performance from slotted motors. This could be implemented in a new motor-series. Key aspects are the design of the magnetic circuit and the winding process on the one hand and improvement of the mechanical design on the other hand. The magnetic flux density could be increased by the use of single sintered segment magnets compared to a commonly used pressed magnetic ring. With the accurate process control of the winding process, wire routing and integrated electrical connection the necessary augmented copperfilling rate could be achieved.

Offline and online parameter identification for the PMSM model for high-frequency and fundamental-wave excitation

Nils Wilcken, Carsten Fräger, University of Applied Sciences and Arts, Hannover, Germany

In this paper, the parametrization of the fundamental wave model and the model for high frequency voltage excitation (HF-Modell) of a permanent magnet excited synchronous machine (PMSM) are presented. Saturation-dependent machine parameters are identified and approximated. This includes a selection of useful mathematical functions as basis, and an optimization algorithm for the approximation. Moreover the results of identification and approximation are made plausible in terms of physical aspects. Finally, the estimated state variables are shown and evaluated by means of measurements.

Abendveranstaltung

19:00 Uhr Weingut Juliusspital, Klinikstr. 1, 97070 Würzburg