Student Forum

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*...in memory of **Prof. Jorma Luomi,** who was very interested in the high-speed drives research of ETH Zurich and made invaluable contributions during his stays at Zurich (*)...*

Novel Machine and Control Concepts for High-Speed Drives

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Abstract

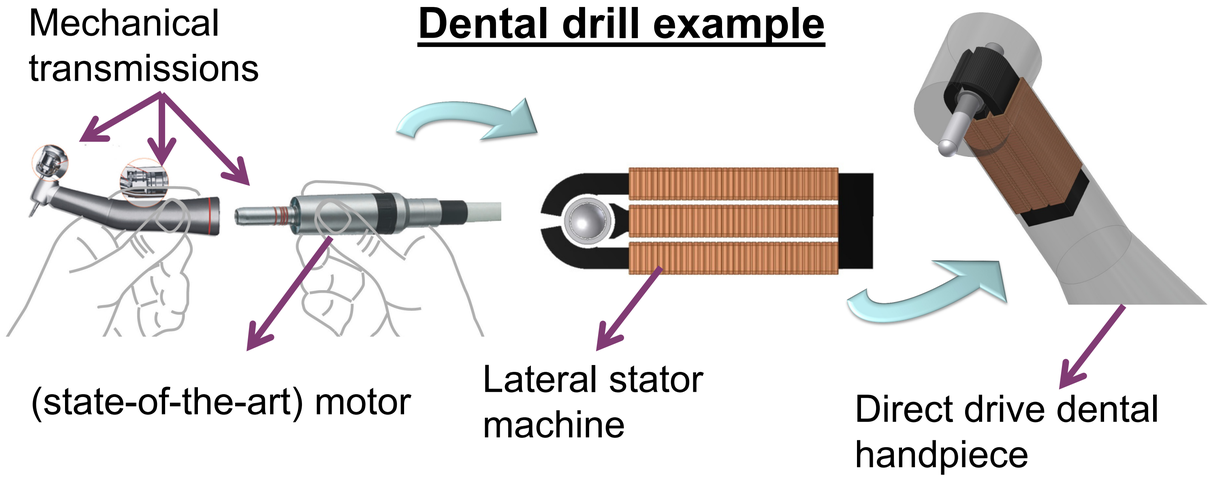
INCREASING the speed of an electrical machine decreases its volume and weight for a given power rating, which is a significant advantage in applications such as generators/starters for micro gas turbines, turbo compressors, micro-spindles and dental/medical drills. Slotless permanent-magnet machine is the machine of choice for typical high-speed applications mainly because of its lower losses. However, the slotless topology also leads to lower torque density and very low saliency. The low torque density is a challenge where the machine needs to fit in confined spaces (e.g. in micro-drills) and the low saliency is a challenge for self-sensing (i.e. sensorless) control of those machines. Those challenges are addressed in this poster and different solutions are proposed.

Novel machine concept for micro-drills [1]

Lateral stator machine (LSM) is a novel machine concept where the stator grows in one lateral direction around the rotor.

Mechanical transmissions

Dental drill example



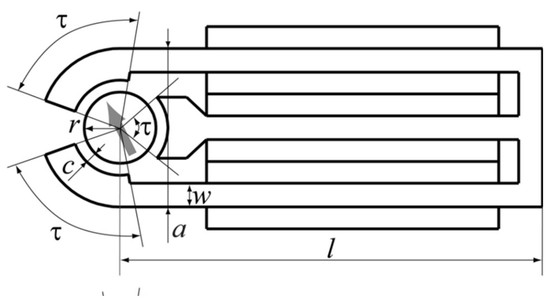
(state-of-the-art) motor

Lateral stator machine

Direct drive dental handpiece

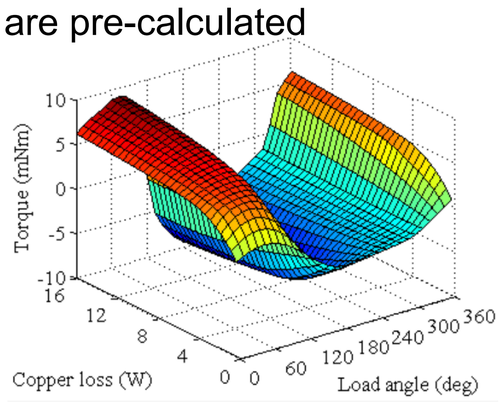
Design and optimization

- FEM analysis
- Geometric parameterization
- >1500 machines simulated
- Best machine selected

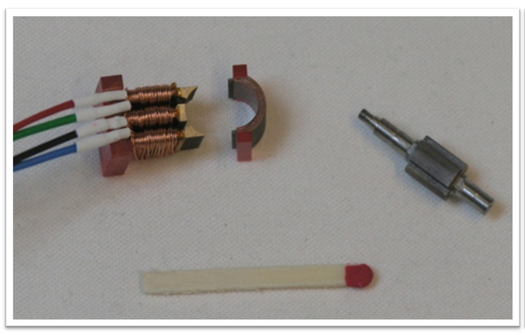


Current profiling

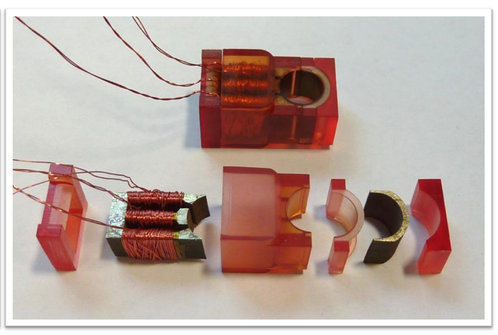
- Stator geometry and saturation lead to high torque ripple
- Currents for smooth torque are pre-calculated



Construction [2]



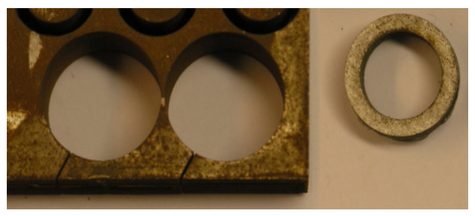
Active parts of the LSM



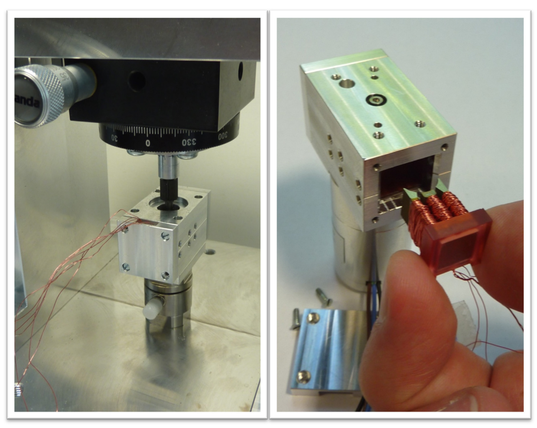
Stator and the 3D printed plastic housing

Effects of the construction method on losses [3]

High-speed machines are usually machined from laminated blocks using electric discharge machining (EDM). The effects of EDM are analyzed both for electrical machines and transformers in [3].



Modular test bench design [2]



Bearingless torque measurement

- No bearing friction
- Direct measurement of electromagnetic torque
- Piezoelectric torque sensor on stator side

Modular no-load loss measurement

- Run-down tests
- Not affected by mechanical losses
- Segregation of electromagnetic losses

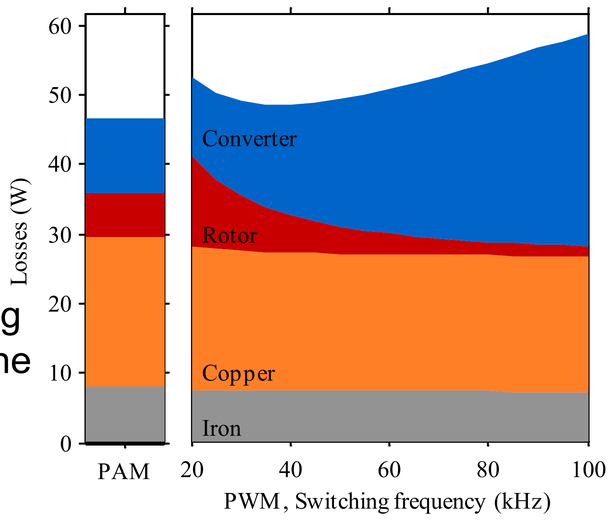
Side projects in collaboration with industry

Self-sensing control of extremely low saliency machines

- A patent application on a novel method of applying voltage pulses to the machine to measure the rotor position in [4]
- Differential measurements for high resolution position estimation of extremely low saliency machines in [5]

Modeling of machine and converter losses for high-speed drives [6]

- Motor and converter losses modeled taking high-speed effects into account
- Different modulations and different motor topologies compared
- Possible advantages of shifting the losses from the motor to the converter explained



Publications

[1] A. Tüysüz, A. Looser, C. Zwyssig, J. W. Kolar, Novel Miniature Motors with Lateral Stator for a Wide Torque and Speed Range, Proceedings of the 36th Annual Conference of the IEEE Industrial Electronics Society (IECON), Phoenix, USA, Nov. 7-11, 2010.

[2] A. Tüysüz, D. Koller, A. Looser, J. W. Kolar, Design of a Test Bench for a Lateral Stator Electrical Machine, Proceedings of the 37th Annual Conference of the IEEE Industrial Electronics Society (IECON), Melbourne, Australia, Nov. 7-10, 2011.

[3] B. Cougo, A. Tüysüz, J. Mühlethaler, J. W. Kolar, Increase of Tape Wound Core Losses Due to Interlamination Short Circuits and Orthogonal Flux Components, Proceedings of the 37th Annual Conference of the IEEE Industrial Electronics Society (IECON), Melbourne, Australia, Nov. 7-10, 2011.

[4] C. Zwyssig, A. Tüysüz, et al., Converter and Method for Driving an Electric AC Machine. European Patent Application, 2011.

[5] A. Tüysüz, M. Schöni, J. W. Kolar, Novel Signal Injection Methods for High-Speed Self-Sensing Electrical Drives, Proceedings of the IEEE Energy Conversion Congress and Exposition (ECCE 2012), Raleigh, USA, September 16-20, 2012.

[6] L. Schwager, A. Tüysüz, C. Zwyssig, J. W. Kolar, Modeling and Comparison of Machine and Converter Losses for PWM and PAM in High-Speed Drives, Proceedings of the International Conference on Electrical Machines (ICEM 2012), Marseille, France, September 2-5, 2012

(*) J.Luomi, C.Zwyssig, A. Looser, J. W. Kolar, Efficiency Optimization of a 100-W 500 000-r/min Permanent-Magnet Machine Including Air-Friction Losses, IEEE Transactions on Industrial Applications, vol. 45, issue 4, pp. 1368-1277, July-Aug. 2009.