TUTORIAL 3

"Self-bearing Linear-Rotary Actuators with Wireless Power Transfer for High-Purity and Precision Applications"

SPEAKER

DDr. Spasoje Miric

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Linear and rotary actuators (LiRAs) are used in high-end applications, such as pick-and-place robots in the semiconductor/pharmaceutical industry or implantable blood pumps, with incredibly high hygiene and high-precision requirements (sub-µm range). Self-bearing actuators should be employed to accomplish such high demands. The self-bearing feature is enabled by integrating magnetic bearings (MBs) into a LiRA or by incorporating a pump into a LiRA where hydraulic bearings (HBs) are realized. Both self-bearing enablers, MBs and HBs, feature high purity since there is no wear-and-tear, and MBs allow for high precision. Finally, the actuator's supply must comply with high hygiene requirements and, therefore, moving cables and cable carriers are replaced by wireless power transfer (WPT) technology enclosed in conductive stainless steel. The WPT system achieves exceptionally high efficiency when the coupling magnetic field is parallel to the stainless steel enclosure sheets.

This Tutorial will first discuss the applications of the LiRAs and highlight the challenges arising from the application requirements and explain how these challenges are overcome with self-bearing LiRAs. We will then focus on the self-bearing LiRAs with MBs, where we will first explain how to incorporate MBs into a linear actuator (LA) and, thereby, within the same volume as the original LA.

We will show how the phase currents of such a newly conceived actuator are decoupled for the combined windings to control the linear drive force and the MB radial force. We will then focus on integrating MBs into a LiRA and show what integration options exist. We will compare these options using scaling laws specially derived for this purpose and clarify which should be chosen regarding the application.

We will explain the automatized geometry optimization for the actuator design, which couples analytic thermal models and numerical magnetic FEM models. Next, we will discuss the implantable LiRA blood pump, where the pumping feature ensures hydraulic bearings of the mover and, therefore, enables self-bearing characteristics. The pump is intended to be used as a total artificial heart, requiring an extremely compact and efficient design of the LiRA. Finally, we will show WPT through stainless steel (SS) technology that is used for supplying moving equipment in environments with high hygiene requirements, e.g., clean rooms in the semiconductor industry. For the discussed topics, hardware demonstrators and measurements that verify newly proposed self-bearing LiRAs and WPT technology will be shown. They highlight the current research on advanced mechatronics at the Power Electronics Systems Laboratory of ETH Zurich.

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BIOGRAPHY

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Spasoje Mirić received B.Sc., M.Sc., and Ph.D. degrees in electrical engineering from the University of Belgrade, School of Electrical Engineering in 2012, 2013, and 2018, respectively, with a focus on power electronics systems and drives. In 2021 he defended his second Ph.D. thesis at ETH Zurich at the Power Electronic Systems Laboratory (PES) in the advanced mechatronic systems area. More specifically, during his Ph.D. project, he focused on linear-rotary actuator systems with magnetic bearings, resulting in two new machine topologies patented.

Since 2021, he has been with PES as a post-doc researcher, focusing on WBG power converter optimization with hard and soft-switching, new modulation techniques of flying capacitor converters, wireless power transfer systems, and eddy-current-based position sensor systems.

In 2023, Spasoje Miric started as an Assistant Professor at the University of Innsbruck, Department of Mechatronics, where he started a new laboratory for drives and energy systems.

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