Optimized PID controller for a 6-DoF magnetic levitation positioning system

Mousa Lahdo[1], Tom Ströhla[2], Sergej Kovalev[1]

[1]Department of Informatics, Electrical Engineering and Mechatronics, University of Applied Sciences Mittelhessen, Friedberg, Germany

[2]Department of Mechatronics, Ilmenau University of Technology, Ilmenau, Germany

Modern high-precision positioning systems with large travel ranges in multiple-degrees of freedom, precisions up to the nm-range as well as vacuum compatibility are required for many applications, such as semiconductor manufacturing or nanotechnology. The ideal solution for such applications is the using of electrodynamic linear motors in combination with active magnetic guidance, which allow the realization of six degrees of freedom (6-DoF) magnetic levitation systems. These positioning systems are characterized by highest dynamic, highest precision and absolutely friction-free operation.

Currently, several magnetic levitation systems can be found in literature, which can be classified by the magnetic forces to levitate the moving element (mover). These levitation forces are generated either by reluctance actuators using reluctance forces to attract the mover or by commutated electrodynamic linear motors with Halbach-Arrays using electrodynamic forces to repulse the mover [1]. Solutions with reluctance actuators allow a relatively simple realization of the closed-loop control due to the decoupled propulsion and levitation forces. However, a compact construction with a freely accessible mover from above cannot be realized. On the other hand, solutions with Halbach-Arrays enable the realization of a compact construction with a freely accessible mover, but these systems require the application of complex control algorithms because of the heavily coupled propulsion and levitation forces.

Based on the analysis of existing magnetic levitation systems, a 2-DoF actuator was proposed in order to overcome the main limitations of reluctance actuators and Halbach-Arrays [2]. One possible positioning system with 6-DoF based on the 2-DoF actuator will be explained (Fig. 1). One metrology concept for the measurement of the 6-DoF, which takes the Abbe principle into account, will also be shown. Moreover, the relation between the sensor measurements and the global position of the mover as well as the mathematical model of the system dynamics will be derived. Based on these results, an optimized PID controller is designed in order to levitate the moving element. Furthermore, it will be experimentally shown that this PID controller can be successfully used to stabilize the moving element with stationary positioning.

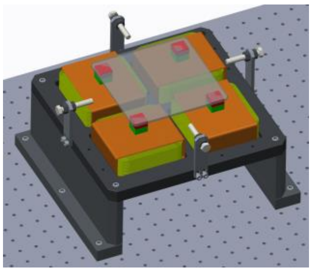

Figure 1. Magnetic levitation system with 6-DoF.

[1] M. Lahdo, T. Ströhla, S. Kovalev, „A Novel High-Precision Positioning System Based on Magnetic Levitation," *1. IEEE Conference on Adances in Magnetics (AIM)*, Bormio, Italy, 2016.
[2] M. Lahdo, T. Ströhla, S. Kovalev, „A Lorentz Actuator for High-Precision Magnetically Levitated Planar Systems," *IEEE International Conference on Industrial Technology*, Toronto, Canada, 2017.