Analysis of an Electromagnetic Levitation Actuator with the Application of Open Source FEM

Degree programme: Master of Science in Engineering | Specialisation: Energy and Environment
Thesis advisors: Prof. Dr. Sébastien Mariéthoz, Prof. Dr. Stéphane Félix
Expert: Dr. Martin Veenstra

In this master thesis an electromagnetic levitation actuator is analysed. The purpose of the actuator is to be used to teach control systems. Through the conceptual analysis possible physical principles are identified. The principle to obtain levitation through generated magnetostatic fields is analysed using the Finite Element Method (FEM).

Felix Alexander Grimm

Initial Situation

In a previous project, a simplistic levitation device was used in the practical exercises of the control systems class at the BFH University of Applied Sciences. This device was adjusted in small steps to improve performance and handling without considering the stator design. This consideration requires the development of a new device, whereby physical limits can be better exploited to achieve an increase in performance compared to the existing device. In addition, a development of a new actuator allows the incorporation of new functionalities. Hence, the meaning functionality is either of technological or didactical nature. This means from a technical aspect, the levitating component can move in different ways, e. g. the translation or the rotation around fixed axes in space. In the sense of a didactic aspect, the actuator is a device to support the learning process of the students who conduct the exercise.

Conceptual Analysis

The goal of the conceptual analysis is to identify possible physical principles to obtain electromagnetic levitation, which can be used in a control exercise class. In a first step, principles are reviewed and conducted in experiments. In a second step, existing levitation actuators are presented to gain insights between functionality and physical structure. A morphological matrix is used to categorize the actuator functionalities with their possible solution principles.

FEM Analysis

The goal of the FEM analysis is the investigation of magnetostatic fields. Different candidates are selected. On the one hand side, the purpose of the candidates is to investigate aspects of the actuator's layout. On the other hand, it is investigated how FEM must be handled with respect to an electromagnetic design. For this reason, the application of FEM is done in the software tools Elmer (open source) and Comsol (commercial). Further, the FEM analysis of the actuator is conducted along analytical analysis and experiments.

Results

Concepts

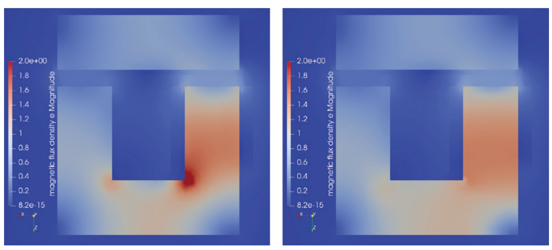
From the findings of the conceptual analysis the inclusion of four different electromagnetic principles is proposed. The principles are electrodynamic levitation, diamagnetic levitation, levitation through the magnetic bound state and electromagnetic levitation through the application of magnetostatic fields. Actuator concepts of the first three principles are proposed through the literature review and the conducted experiments. The added didactic value, to use several principles, is twofold. It enables teaching the control exercise in a stepwise degree of difficulty. Cross-linked knowledge can be achieved through the inclusion of more than one electromagnetic principle in the exercise.

Simulations

The simulated candidates achieve the following four results: - The verification of Biot-Savart law for a closed single current carrying loop (circular, triangular and square-shaped). - The obtained force, energy and inductance values from a gapped UI-Cored coil with linear (permeability) and non-linear (BH-Curve) material settings. - The placement and geometrical variation of magnetizable material in the stationary and levitated part respectively. - The magnetic forces between two opposing permanent magnets.

Conclusion

The analyses lay the foundation to design a levitation actuator which is to be used to teach control systems.



B-Field distribution by an equal current excitation. Simulated with Elmer. Permeability setting left and BH-Curve right.